Delineation of Subsurface Fractures Density Within and Out of Abu-Jir Fault Zone Using 2D Imaging Resistivity Technique, A case Study from Southwest of Karbala City, Central Iraq

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Abstract
The 2D imaging survey was carried out using Wenner-Schlumberger array through (11) 2D survey lines distributed within and out of Abu-Jir fault zone, Southwest of Karbala City, central Iraq. The aim is to delineate subsurface fractures density. The total length of each 2D survey line is (600m.) with the unit electrode spacing (a) equals to (10m.).The results showed two types of fractures zones. The first type is formed by dissolution process of carbonate rocks, while the second fractures zone is formed from tectonic movements, and it includes two types of fractures system, oblique and vertical fractures.
This study includes comparison between subsurface fracture density within and out of Abu- Jir fault zone. This comparison showed that the fracture zones are characterized by increasing of resistivity values within Abu- Jir fault zone to reach (106.1 Ω.m), while it decreases out of this zone to reach (30.9 Ω.m). This is caused by increasing groundwater salinity out of this zone. In addition, the fractures density within Abu- Jir fault zone is more than outer ones, despite they have high resistivity values. In general, they increase with the depth, in (NE) direction within and out of this zone. The results indicated that the best area of groundwater investment is located within Abu- Jir fault zone.

Keywords: 2D Imaging Survey, Fracture Density, Abu-Jir fault zone.

تحديد كثافة الكسور تحت السطحية ضمن وخارج نطاق فالق ابو جير باستخدام تقنية المقاومة النوعية ثنائية البعد، دراسة في جنوب غرب مدينة كربلاء ، وسط العراق

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الخلاصة:
نفذ المسح الكهربائي ثنائي البعد باستخدام ترتيب فنر- شلمبرجر للاقطاب من خلال (11) خط مسح ثنائي البعد، وزعت ضمن و خارج نطاق فالق ابو جير، جنوب غرب مدينة كربلاء المقدسة، وسط العراق،

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للتحديد كثافه التكسرات التحت سطحيه. بلغ طول مسافه النشر لكل خط مسح ثنائي البعد (600م) ، اما المسافة الفاصلة بين الاقطاب فقد كانت (10م).
اظهرت النتائج، ان هناك نوعان من انطقة التكسرات، النوع الاول تكون بسبب عملية الاذابة للصخور الكاربونية، اما النوع الثاني فتكون نتيجة الحركات التكتونية والذي يتضمن نوعين من انظمة التكسرات، التكسرات المائلة و التكسرات العمودية. في هذه الدراسة تم اجراء مقارنة بين كثافة التكسرات ضمن وخارج نطاق الفالق، هذه المقارنة اظهرت ان انطقة التكسرات تتميز بارتفاع قيم المقاومة النوعية داخل نطاق فالق ابو جير لتصل الى(106,1 اوم.متر)، بينما تقل خارجه لتصل الى (30,9 اوم.متر). وهذا نأتج عن زياده ملوحة المياة الجوفية خارج هذا النطاق.

بالاضافة الى ذلك ، فان كثافة الكسور داخل نطاق فالق ابوجير هي اعلى من كثافتها خارجه، وبشكل عام تزداد كثافة هذه الكسور مع العمق في الاتجاه (NE) في كلا المنطقتين . النتائج اشارت بان افضل منطقة لاستثمار المياة الجوفية تقع ضمن نطاق فالق ابو جير.

Introduction

Fractures typically occur in one of two ways - either parallel or perpendicular to normal or reverse faults. They are more common in carbonate rocks than in sandstones and typically occur in specific directions which are dictated by the regional tectonic stresses [1]. The fractures may extend to the surface where they are observed and studied at outcrops. On the other hand, they may terminate in the subsurface or may be covered by overburden which makes them impossible to be studied and characterized at the ground surface. There is an increasing interest in the location and characterization of the fractures by earth scientists, both at the surface and the subsurface. However, the unavailability or inaccessibility of good outcrops makes it imperative to develop methods and tools for studying the fractures in the subsurface. Geophysical methods such as the resistivity methods have been very useful in this regard.

The resistivity method has been used since the 1920s, when it was initially applied for qualitative interpretations, the 1D resistivity surveys were carried out doing either Constant Separation Traverse (CST) or Vertical Electrical Sounding (VES). As a result advances in field equipment design capability and computer algorithms led to appearance of 2D and 3D resistivity techniques in the 1990s. The 2D imaging becomes one of the most significant geophysical techniques for investigating underground structures [2-7]. However, most electrical resistivity surveys for subsurface fracture characteristics were carried out by 1D azimuthal and 2D imaging technique [8-13].

Therefore, the 2D imaging technique will be used to determine the subsurface fracture density within and out of Abu- Jir fault zone, to delineate the best area of groundwater investment.

Site Description

The study area is located south of Al- Razaza Lake, south- west of Karbala city. It forms a part of eastern edge for the Western Desert of Iraq. The area occupies about 1240.8km^2 , and is located between the longitude of (43º 25' – 43º 45') East, and latitude of (32º 10' – 32º 27') North, figure -1.

According to [14], the Abu-Jir fault is one of the typical structures in Iraq, extends toward NW-SE for a hundreds of kilometers on the western side of the Mesopotamian basin. This fault was named Abu-Jir fault zone, because it is formed from two normal faults form the graben structure. The feature of this structure on the ground surface is mysterious and unclear.

The geologic setting of the area (from the oldest to the recent) consists of Umm Er Radhuma formation (Paleocene - early Eocene), Dammam formation (L-U-Eocene), with thickness ranges from (80 to 147m), and Euphrates formation (Lower-Miocene) that has thickness about (10-25m). These Formations are consist of variable carbonate rocks, according to reports of water development project of western desert [15], and General Commission for groundwater [16]. However, Nfayil Formation (Middle Miocene) covers these formations. It has thickness of (1-5m) in the west part of the study area and increasing toward east direction to reach more than (20m).

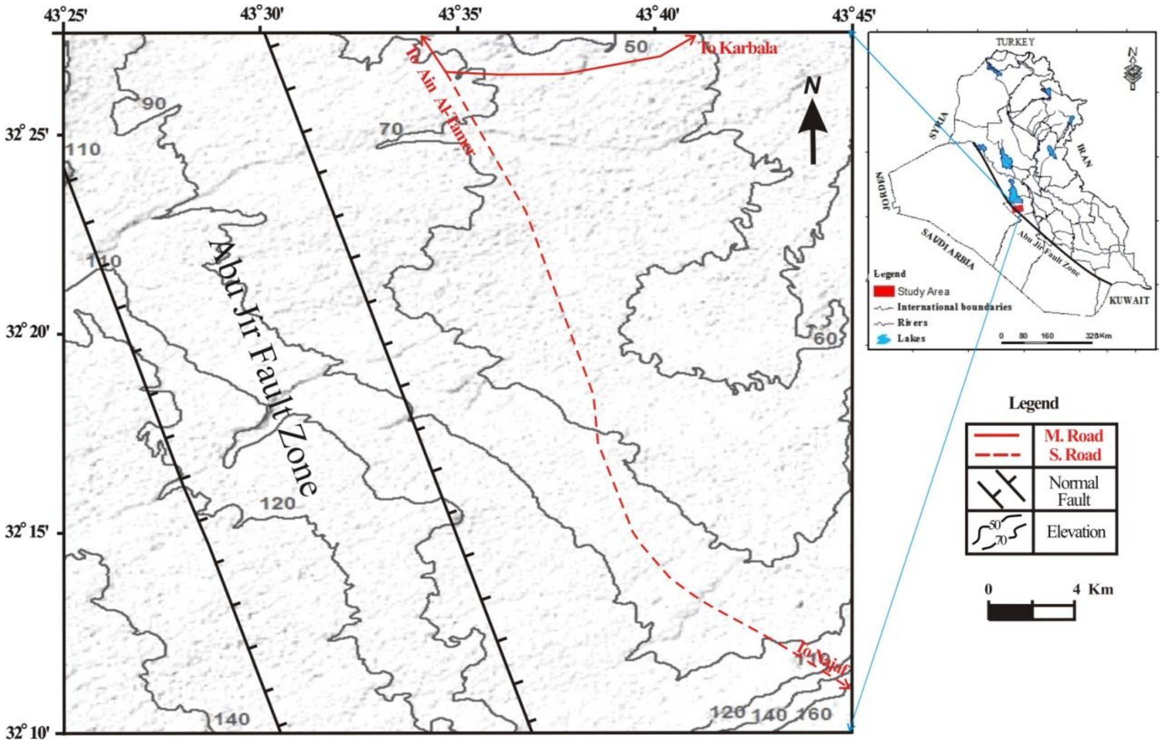

Figure 1- Location and topographic map of the study area by GIS program.

Dammam aquifer is the productive hydrogeological unit in the study area, and it is confined aquifer in most of it. It is characterized by the presence of fractures, cavities and karstification, which play a major role in hydraulic characteristics of this aquifer and distribution of the groundwater [17].

Data Acquisition

The data are collected using SYSCAL pro+ instrument through (11) 2D survey lines distributed within and out of Abu-Jir fault zone, figure -2. All 2D survey lines are carried out in direction (NE-SW), because it is perpendicular on Abu-Jir fault zone. The total length of each line is (600m), where the unit electrode spacing (a) equals to (10m). The Wenner-Schlumberger array is used in this study due to its moderately sensitive to both horizontal and vertical structures. For this reason, this array might be a good compromise between the Wenner and the Dipole-Dipole arrays in areas where both types of geological structures are expected [18].

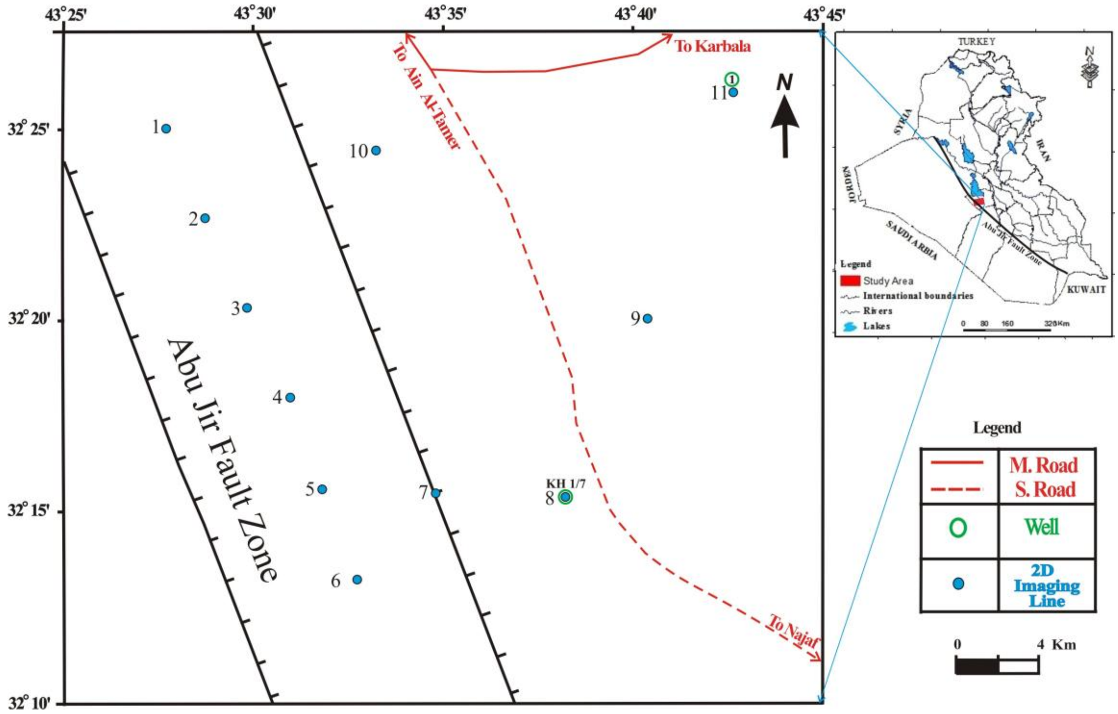

Figure 2- Location map showing the distribution of 2D imaging stations.

The Results

The 2D imaging data have been interpreted through the RES2DINV ver. 3.59 Software [19], by using robust inversion option to the goal reproduce of sharp geologic boundaries.

The inverse models of all 2D survey lines show two types of fracture zones. The first is formed from cavities that are developed from small fractures and fissures through dissolution process of carbonate rocks by infiltration of rainfalls water. In most times, these cavities are connected together by karstification. In some cases, this zone is found as horizontal canal near earth surface. The second fractures zone is formed by tectonic movements, figure -3. These zones, in general are connected together to form one fracture zone, figure -4.

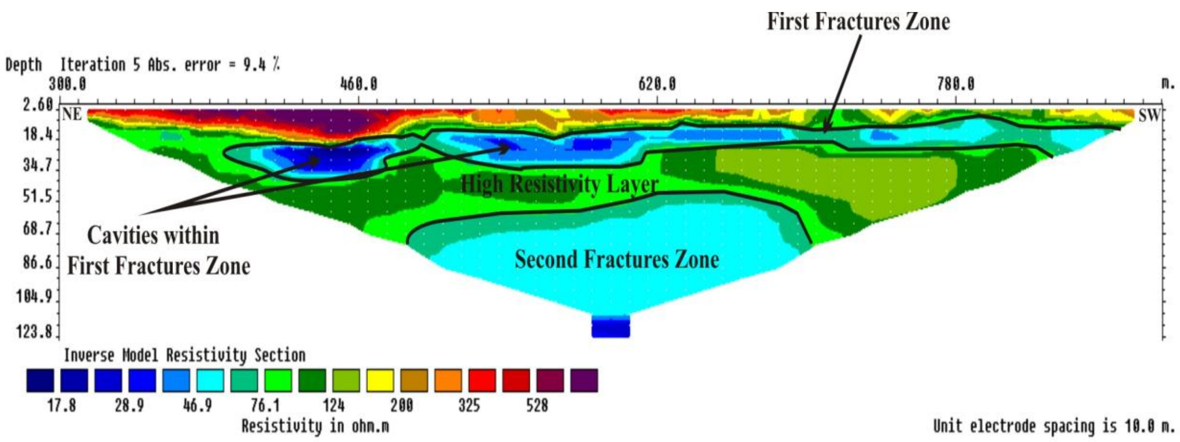

Figure 3 - Shows the types of fractures zones in inverse model of 2D imaging line (4).

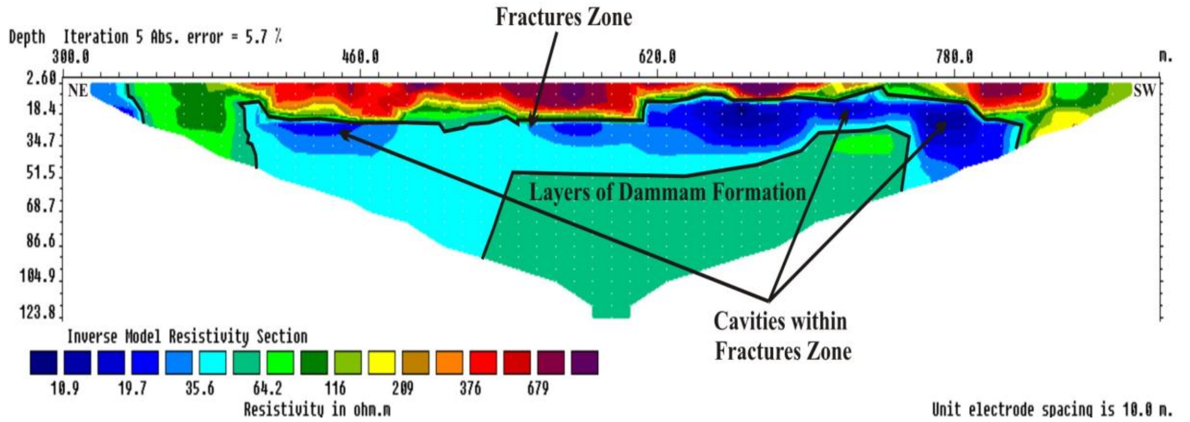

Figure 4 - Shows the connection between the fractures zones to formed one fracture zone in inverse model of 2D imaging line (5).

The second fracture zone includes two types of fracture systems. The first is oblique and the second is vertical fractures, figure -5. The obliquity degree of the fractures may differ from area to another as a result of the different direction of the stress that caused these fractures.

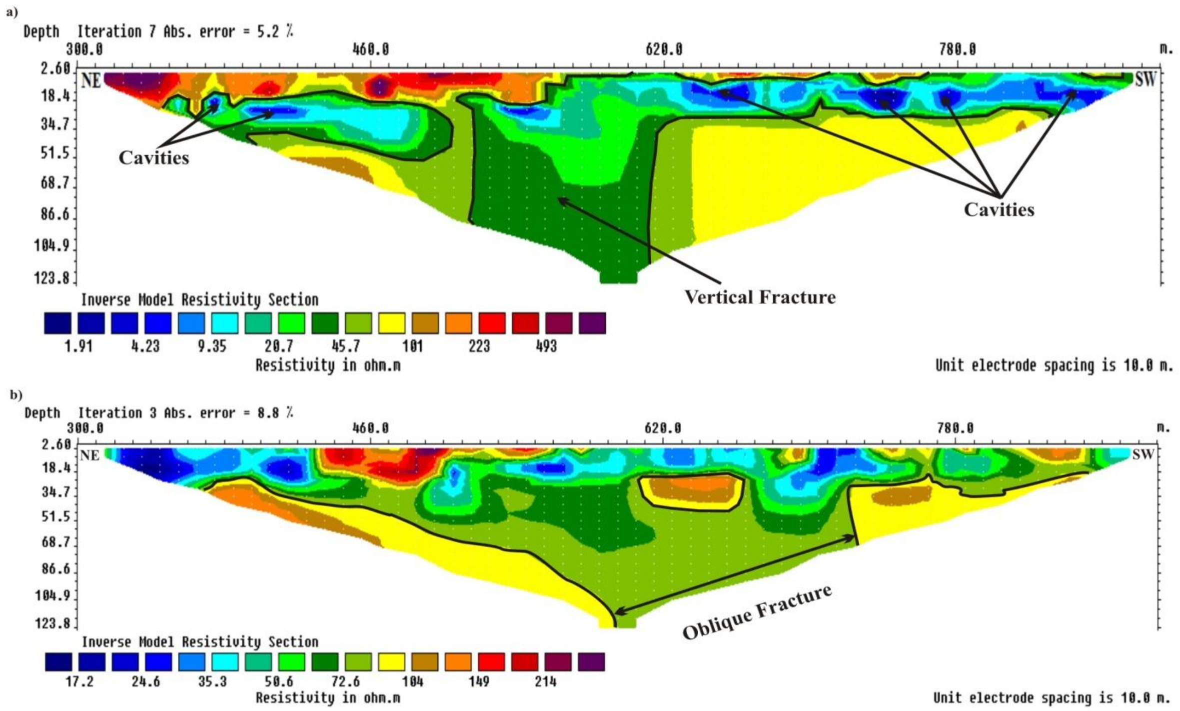

Figure 5- Shows the system types of fracture, a) vertical fracture in 2D imaging line (2), b) oblique fracture in 2D imaging line (3).

Comparison between Subsurface Fracture Density within and Out of Abu- Jir Fault Zone.

The comparison between the results of 2D imaging lines that carried out within and out of Abu- Jir fault zone are showed some important results, which are given in the following:-

1- In general, the fracture zones are characterized by increasing of resistivity values within Abu- Jir fault zone and decreasing out of it. Where the maximum resistivity values of fracture zones within Abu- Jir fault zone were equaled to (106.1 Ω.m) in the 2D imaging line (6). While they are equal to

(30.9 Ω.m) in the 2D imaging line (10) that is located out this zone, figure -6. This is caused by increasing groundwater salinity out of Abu- Jir fault zone. The increasing in the groundwater salinity may be due to increase thickness of the Nfayil and Euphrates Formations, or presence the fracture zones within marly limestone layers with the presence of hydraulic connection between aquifers.

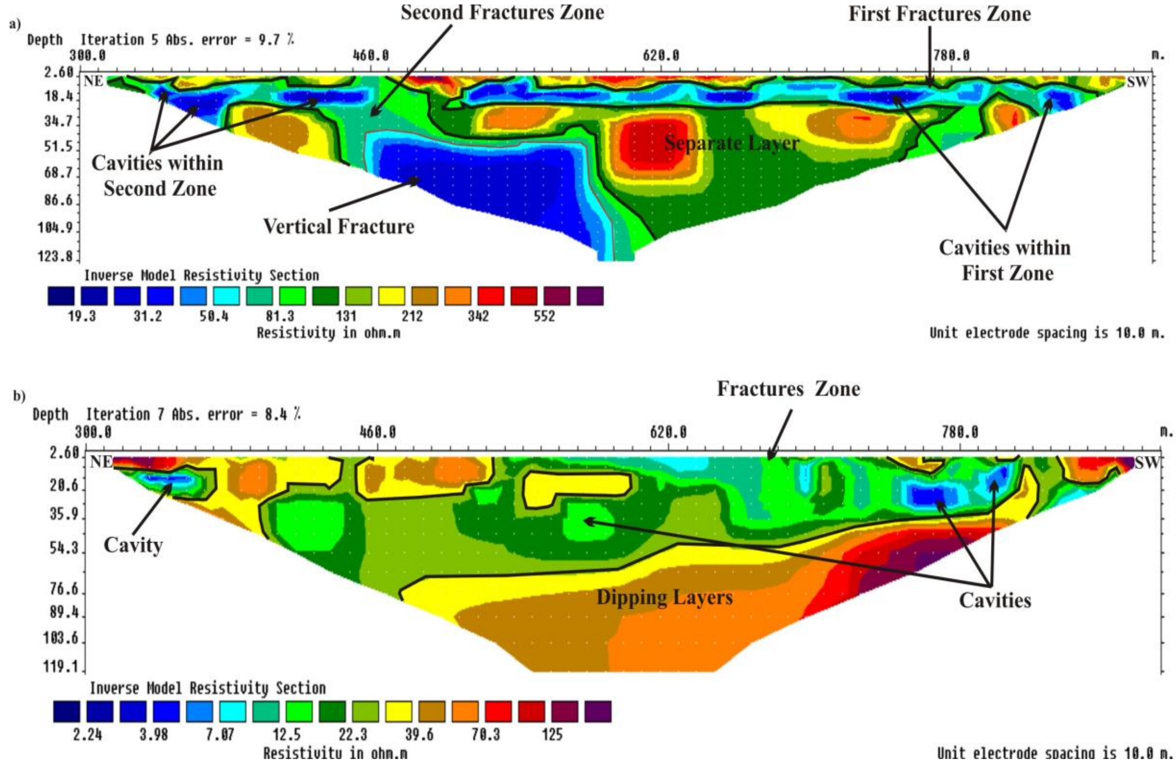

Figure 6- Shows the resistivity values of fracture zones within and outer Abu- Jir fault zone, a) increasing resistivity values in inverse model of 2D imaging line (6), b) decreasing resistivity values in inverse model of 2D imaging line (10).

According to, the spatial distribution of (E.C) map of [20], the (E.C) values of water samples are increased out of Abu- Jir fault zone and decreasing within it, and this is agree with results of this study.
2- The fractures density within Abu- Jir fault zone is more than out of it, despite their high resistivity values. In general, it increases with the depth within and out of Abu- Jir fault zone.
3- In high fracture areas the determination of fracture orientations are very difficult due to the presence of fractures in more directions.
4- All inverse models 2D imaging lines that carried out within and out of Abu- Jir fault zone showed the same fracture system, which are oblique and vertical types.
5- Depending on the results of this comparison, the best area for groundwater investment is that located within Abu- Jir fault zone.

Conclusions

The 2D imaging technique showed some important results, which are given in the following:
1- The results of all 2D imaging lines showed two types of fracture zones. The first is formed from cavities that are developed from small fractures and fissures through dissolution process of carbonate rocks. The second fractures zone is formed from tectonic movements. It includes two types of fracture systems. The first is oblique and the second is vertical fractures.
2- The obliquity degree of the fracture may differ from the area to another, as a result of the different direction of the stress that caused these fractures.

3- The comparison between subsurface fracture density within and out of Abu- Jir fault zone showed that the fractures zones is characterized by increasing of resistivity values within Abu- Jir fault zone and decreasing out of it. This is caused by the increasing groundwater salinity out of Abu- Jir fault zone.

4- This comparison also shows that the fractures density within Abu- Jir fault zone is more than out of it, despite of their high resistivity values. In general, it is increasing with the depth within and outer Abu- Jir fault.

5- Depending on the results of the comparison, it is clear that the best area for groundwater investment is that located within Abu- Jir fault zone.

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References:

1. Golder Associates. **2010.** Fractured bedrock field methods and analytical tools, report submitted to the ministry of environment, submitted by science advisory board for contaminated sites in British Columbia prepared under contract by Golder associates ltd. Burnaby, British Columbia, 2,159 pages.pwest@uvic.ca.

2. Zhou, B., Beck, B. F. and Adams, A. L. **2002.** Effective electrode array in mapping karst hazards in electrical tomography. *Environmental geology*, 42, pp: 922-928.

3. Zhou, Q., Matsui, H. and Shimada, J. **2004.** Characterization of the unsaturated zone around a cavity in fractured rocks using electrical resistivity tomography. *J. Hydraulic Res.*, 42, pp: 25-31.

4. Ford, D.C. and Williams, P.W. **2007.** *Karst Hydrogeology and Geomorphology*, Chichester, p:562

5. Goldscheider, N. and Drew, D.**2007.** *Methods in Karst Hydrogeology, London,* pp:264.

6. Loke, M.H, Chambers, J.E., Rucker ,D.F., Kuras, O. and Wilkinson, P.P. **2013.** Recent developments in the direct-current geoelectrical imaging method. *J. Applied Geophysics*, 95, pp:135–156.

7. AL-Zubedi, A. S., and Thabit, J. M. **2014.** Comparison between 2D imaging and vertical electrical sounding in aquifer delineation: a case study of south and south west of Samawa City (IRAQ), *Arabian J. Geosciences*, 7(1), pp: 173-180.

8. Karaman, Abdullah and and Turhan, K. **2004.** Identification of karst features using seismic P-wave tomography and resistivity anisotropy measurements. *Arabian J. Geosciences, Springer*-Verlag, Online.

9. Ganerod, G. V. , Ronning , J. S., Harald E. D., Holmoy, E.K. and Braathen , A . **2006.** Comparison of geophysical methods for sub-surface mapping of faults and fracture zones in a section of the Viggja road tunnel, Norway. *Arabian Journal of Geosciences*, *Springer*-Verlag, Online.

10. Massoud, U., Qady, G., Metwaly, and Santos, F. **2009.** Delineation of Shallow Subsurface Structure by Azimuthal Resistivity Sounding and Joint Inversion of VES-TEM Data: Case Study near Lake Qaroun, El Fayoum, Egypt. *Pure and Applied Geophysics*, 166 , pp:701–719.

11. Odoh, B. I. **2010.** Electro-hydraulic Anisotropy of Fractures in parts of Abakaliki, Ebonyi State, Nigeria using ARS method. *International Archive of Applied Sciences and Technology*, 1, (1), pp: 10 – 19.

12. Obiadi, I.I., Onwuemesi, A.G., Anike, O.L., Obiadi, C.M., Ajaegwu, N.E.,Anakwuba, E.K., Akpunonu, E.O and Ezim, E.O. **2012.** Imaging subsurface fracture characteristics using 2D electrical resistivity tomography. *International Research J. Engineering Science, Technology and Innovation (IRJESTI)*. 1(4), pp: 103-110.

13. Ramachandran, K. B. Tapp, T. Rigsby, T.and Erin, L. **2012.** Imaging of Fault and Fracture Controls in the Arbuckle-SimpsonAquifer, Southern Oklahoma, USA, through Electrical Resistivity Sounding and Tomography Methods. *Hindawi Publishing Corporation International J. Geophysics* .Volume 2012, Article ID 184836, p:10..

14. Fouad, S.F. **2004.**Contribution to the Structure of Abu Jir Fault Zone. *Iraqi Geological J.* 32(33), pp: 63-73.
15. Consortium ,Y. **1977.** Water Development Project Western Desert, Block-7, Hydrogeological exploration and Hydrotechnical works, *Climatology and Hydrology final report*..1,p: 39 p.
16. G.C.G.W. **2013.** General Commission for Groundwater, Karbala Project, Data of the Drilled Wells, Iraq.
17. Al-Mubarak, M. and Amin, R.M. **1983.** Regional mapping of south and western desert of Iraq. Int. rep. GEOSURV Library, No., 1380. Baghdad, Iraq.
18. Loke, M.H, **2012.** Tutorial: 2-D and 3D Electrical Imaging Surveys, p:165p.
19. Geotomo software, **2010.** RES2DINV ver. 3.59. 2D Resistivity and IP inversion program. WWW.geoelectrical.com.
20. AL-Shamari, M. M., **2014.** Groundwater quality evolution in Tar AL-Sayyed area, South Razaza Lake, Central Iraq. M.Sc. Thesis Department of Geology, college of Science, University of Baghdad, Iraq, p: 145.