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Subsurface Structures Delineation to Evaluate the Possibility of Groundwater Gathering Using Gravity Data Interpretation in Salman Basin, Iraqi Southern Desert

Aqeel Rahman [1*], **Inass Almallah [2]** and **Ahmed Mousa [3]**

1 College of Science, University of Basrah, Akeelrahmen@Gmail.com, Basrah, Iraq.

2 College of Science, University of Basrah, inass.abdal_qader@uobasrah.edu.iq, Basrah, Iraq.
3 Iraq Geological Survey, mousa.geoiraq@gmail.com, Baghdad, Iraq.

***Corresponding author email:** Akeelrahmen@Gmail.com; mobile: 07800355534

تحديد التراكيب تحت السطحية لتقييم إمكانية تجمع المياه الجوفية باستخدام تفسير بيانات الجاذبية في حوض سلمان، الصحراء الجنوبية العراقية

عقيل رحمن*[1]، ايناس الملاح[2]، احمد موسى[3]

1كلية العلوم ، جامعة البصرة ، Akeelrahmen@Gmail.com، البصرة، العراق
2 كلية العلوم، جامعة البصرة، inass.abdal_qader@uobasrah.edu.iq، البصرة، العراق
3هيأة المسح الجيولوجي العراقية ، mousa.geoiraq@gmail.com، بغداد، العراق

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ABSTRACT

Background:

The study area is located in the Southern Part (SD) of Iraq, between the Southwestern part of Al-Samawah city and northeastern part of Dhi-Qar Governorate. The lack of surface water for different usages requirements has led to search for new groundwater resources. The study area is characterized by an arid to semi-arid climate with little rains and increase evaporation.

Materials and Methods:

Gravity methods and using GIS environment were used to delineate the subsurface structural lineaments in Salman Basin (SB) within Al-Muthanna province in Iraqi southern desert (SD). The Centre for Exploration Targeting (CET) was applied to gravity data; we were used CET technique to find any fractures, contact or faults that may occur within the study area. The data processing was carried out by using the OASIS montaj ™. Data is extracted from the Shuttle Radar Topography Mission (SRTM), Digital Elevation Model (DEM) with a spatial resolution of 90 m, and (land-sat 8) Image are used with Arc GIS Environment for delineation of the secondary basins (Abu-Hadeer, Al-kasir, Ashali, Kor al-tair, Shuwija, Abu marys).

Results:

The interpretation of the gravity data shows two prominent sets of lineaments. The first set is taken NW-NE direction perpendicular to the extensional structures, while the second set has NS-EW direction. Areas with high lineament density have the highest permeability, which means they have a higher possibility of gathering groundwater.

Key words:

Gravity methods, Groundwater, Lineaments, Salman basin, Iraq.

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الخلاصة

تقع منطقة الدراسة في الجزء الجنوبي من العراق بين الجزء الجنوبي الغربي من مدينة السماوة والجزء الشمالي الشرقي من محافظة ذي قار. أدى نقص المياه السطحية نتيجة الاستخدامات المختلفة إلى البحث عن مصادر للمياه الجوفية. تتميز منطقة الدراسة بمناخ جاف إلى شبه جاف مع قلة الأمطار وزيادة التبخر. تم استخدام طرق الجذبية مع برنامج نظم المعلومات الجغرافية (GIS) لتحديد الخطيات التحت السطحية في حوض السلمان ضمن محافظة المثنى في الصحراء الجنوبية من العراق. تم تطبيق (CET) على بيانات الجاذبية، للعثور على أي تشققات او فوالق قد تحدث داخل منطقة الدراسة. تمت معالجة البيانات باستخدام OASIS Montaj ™. البيانات المستخرجة من المكوك الفضائي (SRTM)، ونموذج الارتفاع الرقمي (DEM) بدقة مكانية تبلغ 90 مترًا، والصور المستخرجة من (land-sat 8)، حيث تم استخدام برنامج نظم المعلومات الجغرافية (GIS) لتحليل وتحديد الأحواض الثانوية (أبو حضير، الكصير، الأشعلي، كور الطير، الشويجة، أبو موريس). يضهر تفسير بيانات الجاذبية مجموعتين رئيستين من الخطيات. المجموعة الأولى تكون باتجاه (الشمال الغربي – الشمال الشرقي) حيث تكون بشكل عمودي على التراكيب الواسعة والطويلة، بينما المجموعة الثانية تكون باتجاه (شمال– جنوب وشرق– غرب). المناطق ذات الكثافة العالية من الخطيات تتمتع بنفاذية عالية، مما يعني أن لديها احتمالية أكبر لتجميع المياه الجوفية، وخاصة مواقع تقاطعات الخطوط.

مقدمة:

تعد المياه الجوفية أحد أهم المصادر الطبيعية للتنوع البيئي الذي يعزز صحة الإنسان والنمو الاقتصادي، خاصة في المناطق التي تعاني من ندرة موارد المياه السطحية. لقد برز كمصدر هام للغاية لتوفير المياه في جميع المناطق المناخية، بما في ذلك المناطق الحضرية والريفية في البلدان المتقدمة والنامية. تعتبر المياه الجوفية مهمة في الدراسات الهيدروجيولوجية، خاصة في المناطق التي تعاني من نقص في موارد المياه السطحية، بالإضافة إلى ندرة هطول الأمطار في المناطق القاحلة وشبه القاحلة مثل الصحراء الجنوبية للعراق. تعد الاكتشافات الهيدروجيولوجية لأنظمة الخزان الجوفي ومعرفة الخصائص المياه الجوفية ضرورية لتوفير الطلب على المياه في المناطق القاحلة. يعتبر حوض سلمان من أكثر المناطق الواعدة للزراعة والمشاريع الإسكانية والمراعي حيث توجد العديد من المناطق المشجعة للاستثمار في المياه الجوفية. تُستخدم الطرق الجيوفيزيائية المختلفة، خاصةً طرق المقاومة،الكهرومغناطيسية،المغناطيسية، والجذبية، بشكل شائع في استكشاف المياه الجوفية. تُستخدم طريقة الجذبية للكشف عن الاتجاهات التركيبية التي تتحكم في هندسة الإقليمية لخزانات المياه الجوفية. تتضمن طريقة الجاذبية قياس مجال الجاذبية الأرضية في مواقع محددة على سطح الأرض لتحديد تغيرات الكثافة تحت السطحية. تعمل طريقة الجاذبية عندما يكون للأجسام المدفونة كتل مختلفة، والتي تسببها كثافة الجسم أكبر أو أقل من كثافة المادة المحيطة. يمكن استخدام الشكل النهائي لبيانات الجاذبية المعالجة في العديد من المشكلات الهندسية والبيئية، بما في ذلك تحديد سمك طبقة التربة السطحية أو القريبة من السطح، التغيرات في مستويات منسوب المياه الجوفية، اكتشاف الأنفاق المدفونة، الكهوف، والمنخفضات الارضية، وكذلك الفوالق القريبة من السطح. أيضًا، يمكن استخدام الاختلافات الزمنية لحقل الجاذبية لتحديد الاختلافات في منسوب المياه الجوفية، وتغير مستويات الهبوط في المنخفضات الارضية. يمكن أن تكون طريقة الجذبية تقنية جيوفيزيائية سهلة الأداء والتفسير. لا يتطلب الأمر سوى معالجة بيانات بسيطة ولكنها دقيقة وللدراسات التفصيلية، فإن تحديد ارتفاع المحطة هو الجانب الأكثر صعوبة واستهلاكًا للوقت. بالإضافة إلى ذلك، يمكن الحصول بسهولة على الحدود الجانبية للتراكيب التحت السطحية خاصة من خلال قياس مشتقات مجال الجاذبية. تهدف الدراسة الحالية إلى معرفة التراكيب تحت السطحية للخزان الجوفي العميق من خلال الاستقصاء الجيوفيزيائي وإعطاء تقدير لمكان تجمع المياه الجوفية تحت السطح.

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طرق العمل:

تم الحصول على خريطة بوجير المرصودة للمنطقة بواسطة هيأة المسح الجيولوجي العراقية وشركة البترول العراقية (IPC) . تم تصحيح قيم الجاذبية المقاسة لتصحيحات الجاذبية المختلفة مثل الانجراف والمد والجزر والهواء الحر وتصحيحات بوجير وخط العرض والطبوغرافية باستخدام برنامج Geosoft المتخصص. تم استخدام قيم الجاذبية المصححة لرسم خريطة شذوذ بوجير. في هذه الدراسة، تم حساب الخرائط المتبقية لبيانات الجاذبية من خلال تطبيق (upward continuation)، وبعد ذلك تم طرح الشبكة الجديدة من الشبكة الأساسية للجاذبية. تم استخدام (upward continuation) لتحليل شذوذ بوجير إلى المكونات المتعلقة بالأعماق الضحلة نسبيًا (الشذوذ المتبقي) وتلك من مصادر أعمق (الشذوذ الإقليمي). تم استخدام الفلاتر للبيانات الجذبية لتحديد حواف أو حدود الأجسام الجيولوجية.

الاستنتاجات:

1-تتكون الجيولوجيا تحت السطحية للمنطقة الحالية من تتابع أفقي تقريبًا من الحجر الجيري والصخور المتبخرة لتكوين الرص، وتكوين أم الرضومة، وتكوين الدمام، وتتميز المناطق التي يوجد فيها الحجر الجيري ويكثر فيها المنخفض الارضي (sinkholes)، والتي تكونت بسبب الذوبان بواسطة الماء.

2- خريطة بوجير للمنطقة المدروسة تعكس بشكل أساسي التراكيب التي تقع فوق الطابق السفلي، أي تشوهات الغطاء الرسوبي وهذه الحالات الشاذة تكمل تلك الموجودة خارج منطقة الدراسة الحالية.

3- تحتوي منطقة الدراسة على تدرج جذبية عالي قد يكون مرتبطاً بوجود المنخفضات، يبدو أن معظم هذه الميزات ذات نطاق جانبي صغير مقارنة بالحوض المليء بــ الرواسب التي تحتوي على الاملاح.

4- أشارت التفسيرات التفصيلية للشذوذ المحلي المتبقي إلى إلى أنها ضحلة لتلبية الشذوذ المرصود، وهذا يعني أن عملية الحل قد أثرت على تكوين الدمام بالإضافة إلى تكوين الرص، على عمق يتراوح من 100 متر إلى 450 م

5- شذوذ الجذبية السلبي (اللون الأزرق) مكمل للشذوذ السلبي للمنطقة المدروسة. هذا الشذوذ محاط بتدرج جذبية عالي قد يكون مرتبطاً بوجود الفوالق في منطقة الدراسة: فالق سوق الشيوخ، وفالق انصاب- بصية، في وسط والجانب الشرقي من منطقة الدراسة.

6- يظهر تفسير بيانات الجذبية مجموعتين رئيستين من الخطيات. المجموعة الأولى تكون باتجاه (الشمال الغربي – الشمال الشرقي) حيث تكون بشكل عمودي على التراكيب الواسعة والطويلة، بينما المجموعة الثانية تكون باتجاه (شمال- جنوب وشرق- غرب). المناطق ذات الكثافة العالية من الخطيات تتمتع بنفاذية عالية، مما يعني أن لديها احتمالية أكبر لتجميع المياه الجوفية، وخاصة مواقع تقاطع الخطوط، بينت الدراسة لا توجد هناك علاقة بين الخطيات بمختلف الاتجاهات مع انماط التصريف الشكل 9.

7- تعتبر ظاهرة التخسف من السمات الرئيسية في منطقة الدراسة، كذلك وجود الوديان الرئيسية الممتدة من الأراضي السعودية إلى منطقة الدراسة مصدراً لتجمعات المياه الجوفية وتكوينات التغذية، وخاصة تكوين أم الرضومة وتكوين الدمام وتكوين الرص.

الكلمات المفتاحية: طريقة الجذبية، المياة الجوفية، الخطيات، حوض السلمان، العراق.

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1. INTRODUCTION

Groundwater is one of the most essential natural sources for ecological variety that promotes human health and economic growth especially in regions has scarcity in surface water resources. It has emerged as an extraordinarily significant and impenetrable source of water provide in all climatic regions, inclusive of each urban and rural area of developed and developing countries [1]. Groundwater is important in hydrogeological studies, especially in areas that suffer from a shortage of surface water resources, in addition to a paucity of rainfalls in arid and semiarid regions like the southern desert of Iraq. In arid regions, hydrogeological investigations of aquifer systems and characterization of groundwater resources are required to supply water demand[2]. The Salman Basin (SB) is one of the most promising areas for agriculture, housing projects, grazing areas where there are many areas encouraging investment in groundwater. Different geophysical tools, especially resistivity, electromagnetic, magnetic, and gravity methods, are commonly used in groundwater exploration. The gravity method is used to detect the structural trends controlling the regional geometry of the groundwater aquifers [3]. The gravity method works, when buried objects have differing masses, which is caused by the object having a higher or lower density than the surrounding material. The processed gravity data in its final form can be used to solve a variety of engineering and environmental problems, such as determining the thickness of the surface or near-surface soil layer, changing water table levels, and detecting subterranean tunnels, caves, sinkholes, and near-surface faults. The gravitational field's temporal variations can also be utilized to determine changes in the water table and sinkhole subsidence levels[4 and 5]. The gravity method is a simple geophysical technique that can be performed and interpreted. It simply requires but precise data processing, and the most difficult and time-consuming component of detailed studies is determining a station's elevation. Furthermore, lateral borders of subsurface features can be easily determined, particularly by the measurement of gravitational field [6].

Several previous studies have been presented in different location like [7], gravity and magnetic surveys to delineate subsurface structures in Hor Al-Huwazah area, South of Iraq. [8], performed geophysical measurements for subsurface mapping and groundwater exploration at the central part of the Sinai peninsula, Egypt.[8], delineating groundwater aquifer and subsurface structures using integrated geophysical interpretation at the western part of Gulf of Aqaba, Sinai, Egypt. [9], gravity evidence of widespread solution was detected below Salman area, the Iraqi (SD).

The present study aims to estimate the subsurface situation of the deep aquifer through the geophysical investigation, delineating the subsurface structures, and give an estimation of where the groundwater assemblages under the surface.

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2. Location of the Study Area

The present study area is located at in the southern part of Iraq, to the Southwest of Al-Samawah city at Al-Muthanna governorate. Figure (1) shows the boundary location for the study area, and (Table1) determine the coordinate in longitude-latitude. This area is separated from the regional groundwater basin known as Al-Shbecha-Salman Basin that covers an area of (29,518) Km^2 inside Iraq [10].

Table 1. Coordinates of the boundary locations of study area

Points	Latitude	Longitude
A	31°25'	44°45'
B	30°41'	45°50'
C	29°08'	45°26'
D	29°12'	44°42'
E	29°51'	43°51'

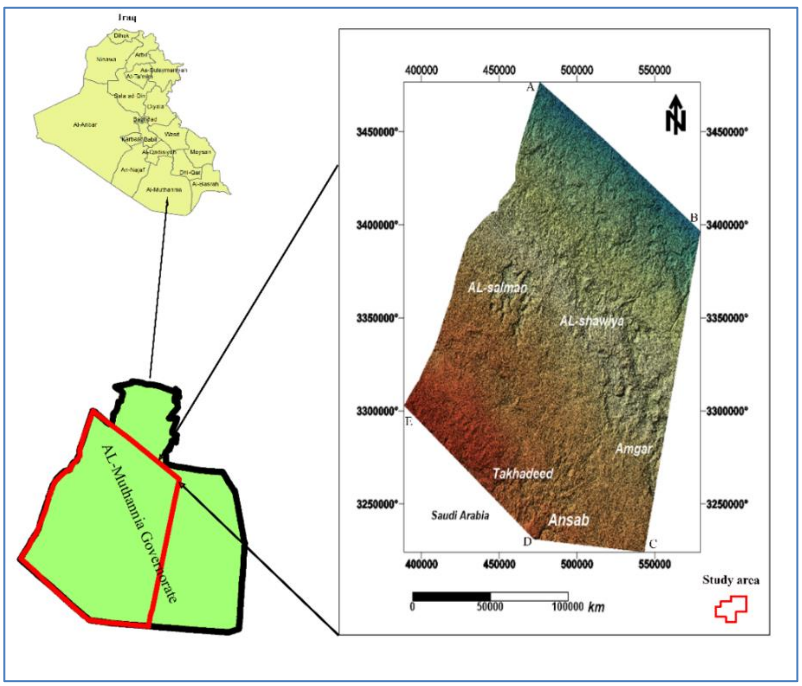

Fig.1. Location map of study area.

3. Geological Setting

3.1 Geology of the study area

The stratigraphic column within the study area comprises formations from oldest to youngest, Umm Er Radhuma Formation, Rus Formation, Dammam Formation, Euphrates Formation, Ghar Formation, Dibdibba Formation, Zahra Formation, and Quaternary Deposits. All the exposed rock units belong to the Cenozoic [11], where the oldest formation is Umm Er Radhuma (Middle-Late Paleocene), which exposed on the Iraqi – Saudi Arabian border of the study area. It subdivided into two members depending on the lithological, and faunal variations, and ranges from 310 to 450 m thickness of anhydrite, and dolomitic limestone, mostly white or buff microcrystalline and permeable [12]. The formation slopes gently northwards and northeastwards. It is overlain by the Rus Formation (Early Eocene) with 90m thickness, that mostly consist of anhydrite with some limestones and marl alternate in its middle parts. The lower part of the Rus formation consists of shale, limestone-dolomitize, and soft chalky limestone. This lithology is found mainly in the deep wells of the Mesopotamian basin [13]. According to [11], the main source of groundwater in the present study area is Dammam Formation, Figure (2). It is overlain by the (Upper- Middle Eocene) Dammam Formation, which is ranges 150 -200m thickness, it consists mainly of mutable carbonate limestone (dolomitic, or chalky) rocks. The bottom of Dammam formation consists of marl beds -chalky limestone and gray-green waxy shale layers [14]. Euphrates Formation in (Early Miocene) is underlain by unconformable within Dammam Formation in the Southern Desert. It consists mainly of basal breccias and is clear by strata of pebbles, and carbonates cobbles. Ghar Formation: (Early Miocene), consists of (2-3) m basal breccia, rare anhydrite, gypsum, clay and sandy calcareous interbreed, rarely fossiliferous, and sand and gravel. The Ghar Formation is exposed, as a discontinuous ridge until NE of Salman town, as overlap within the Euphrates Formation, and unconformably overlies several formations. The Dibdibba Formation is exposed between, Busaiya, Iraqi-Kuwait, and Saudi Arabia's borders. It contains major sandstone, conglomerate sandstone partly cemented by limestone, and gravel (grey and brownish-grey), in the southwestern part of the Busaiya town, which are popular in the area. The Zahra Formation (Pliocene – Pleistocene) forms of white and pink limestone, occasionally sandy marl, and calcareous sands. The formation within the Southern Desert outcrops in a low topographic area concerning the surrounding older rocks [15]. It forms parts of the floor of the Salman topographic depression [16]. The magnetized basement rocks of Iraq are not exposed at the surface, also, there are no boreholes dug to penetrate the whole thickness of the sedimentary cover. Therefore, available information concerning the depth and properties of the basement rocks are predicted indirectly from some geophysical studies. The model of basement rocks depth was conducted with the support of geological information which depended on the thickness of the mega sequence[14]. The depth to the basement rocks in Iraq is the consequence of complicated iteration between geological estimates and 3D inversion of gravity data. The modeling was depends on outcrops and drilled wells from Iraq and neighboring countries. There are few studies on the lineaments in the study area; the main reliance is on the reports and studies of the Iraqi Geological Survey and the

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Geology of Iraq[14]. The study area is located between several major lineaments [14]. The Euphrates fault Zone (Najd Fault System), borders the study area from the north and goes alongside the Euphrates River. The fault zone, which is made up of a sequence of step faults and grabens, marks the transition between the Quaternary Mesopotamian Plain, and the rocky desert. Tar Al Jil Fault Zone (Najd Fault System) runs parallel to and to the south of the Iraqi-Saudi border. It's part of a Paleocene escarpment that faces a depression filled with Mio-Pliocene clastics and freshwater limestones. Takhadid-Qurna Fault Zone (Transversal System), divided the study area into two parts.

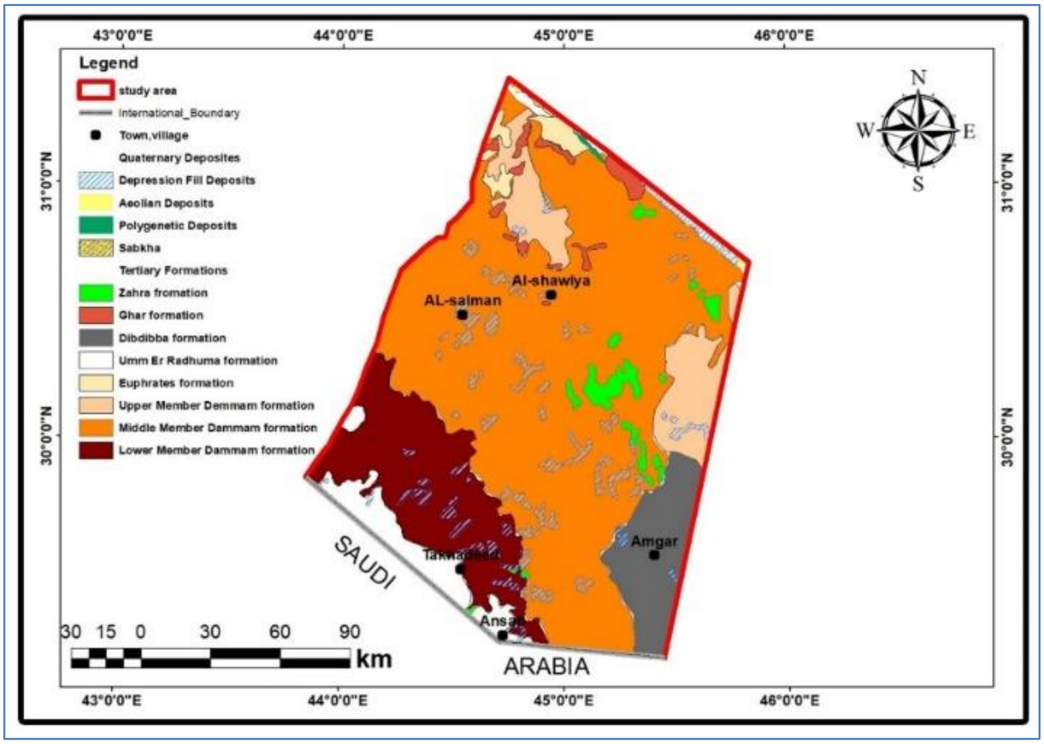

Fig.2. Geological map of the study area, after (Sissakian and Fouad (2000)

3.2 Geologic structures

Structurally, the Salman basin lies within the Platform of the Arabian Plate and in particular within the Salman Zone [18], where the Cenozoic succession is exposed and slopes gently towards the Mesopotamian basin; beyond the Euphrates River to the north of the area. There are several major lineaments in the study area[14]. It is located within the eastern boundaries of the southern desert, the most important faults in the area are: Tar Al Jil Fault Zone runs along the Iraqi-Saudi border bounded the study area at southwestern side, the Safawi-Samawa Fault bounded at west side, Takhadeed -Suq Al-Shoyokh Amara fault, Ansab- Al-Busaya- Qurna Fault located within and east side of the study area, and the Euphrates Fault located N-NE of the study area [19] Figure (3).

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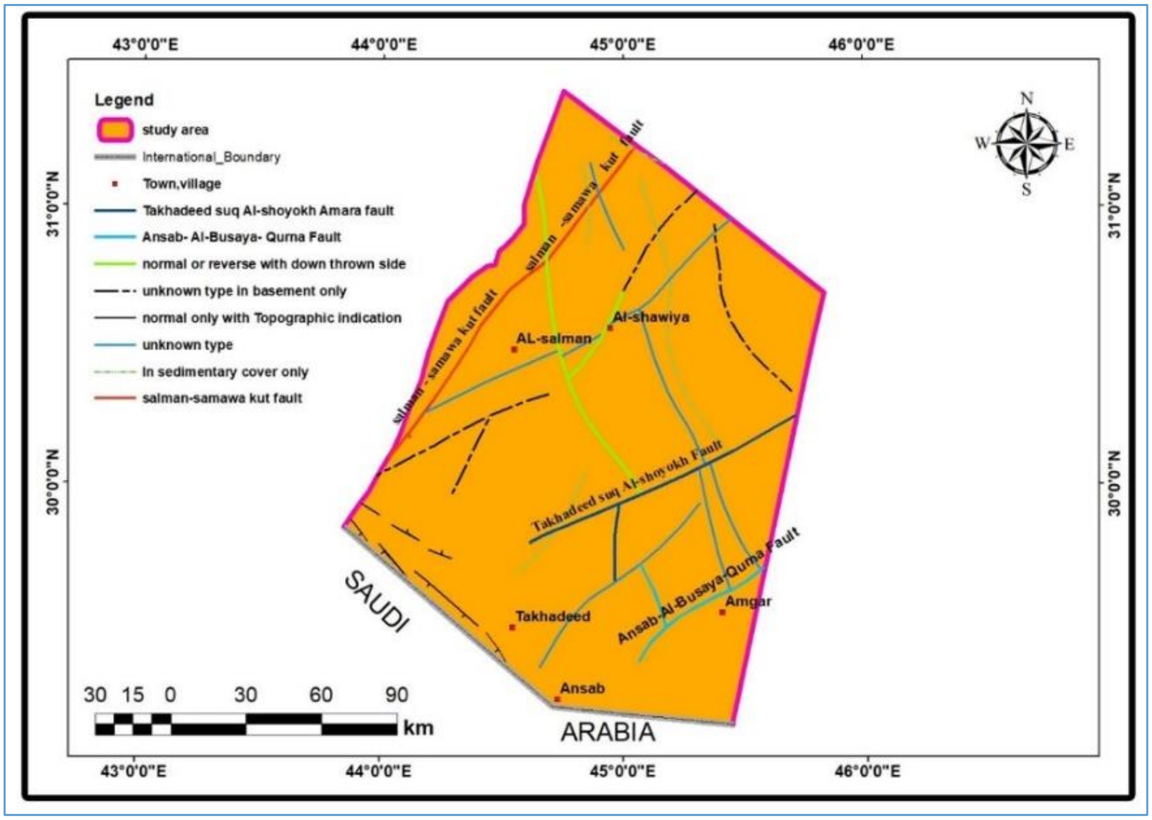

Fig.3. Structural map of the studied area, (modified from GEOSURV. 1996, Tectonic map of Iraq).

3.3 Geomorphology

The present study region is a flat plain rising gently towards southwest and west, intensely dissected by valleys, which show different karst forms[20]. The valleys are wide and shallow, trending generally towards north and northeast, however they exhibit very complex and abnormal drainage shapes, due to intense karstification. During the Neogene, the southern desert is believed that alternating arid continental and shallow marine environments[21]. As a result, during the Oligocene continental period, the higher topography was subjected to both mechanical and active chemical weathering (solution) produced by groundwater[22]. The first subterranean cavities and hollows were formed. These were eventually developed, after the Miocene, some of them collapsed, while others collapsed throughout the Pleistocene and Holocene and are currently collapsing[23]. The collapse was caused by the expansion of chambers and the thinning of roofs, and there was no tectonic influence. The shapes, sizes, and extents of a number of these hallows found in the southern desert were described by [24].

Limestones from the Dammam Formation are evident in the cliffs. Caverns are subterranean hallows that have been extended by solution and erosion, eventually producing massive collapse sink depressions with lengths and widths of tens of kilometers.

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Sissakian and Ibrahim (2005), pointed that the sinkholes are common types in the southern desert, which are developed due to dissolving of limestone. Sinkholes are also well developed in the anhydrite land, which can be named as Limestone Pavement, It consists of hundreds of sinkholes, which are filled by polygenetic sediments [25].

4. Basin Delineation Based on Satellite Data

Surface runoff is usually discharged through the lowest point at the drainage basin's outlet. The basin is a hydrologic system unit in which all input precipitation is released as stream flow through the outflow unless it is lost through abstraction processes such as infiltration[26]. GIS (geographic information system) is a powerful tool for overlaying maps with various thematic data and for map integration and analysis[27]. Data from the Shuttle Radar Topography Mission (SRTM DEM) with a spatial resolution of 90 m, and (land-sat OLI 8) Image are used for delineation data of the basin and the stream networks in the area. The hydrological spatial analyst tools by preforming a series of steps, fil, flow accumulation, flow direction, then used to automate calculation of the study area. The results of the analyses showed that the region is containing of six watersheds: (Abu-Hadeer, Al-Kasir, Ashali, Kor al-Tair, Shuwija, and Abu Marys). In general, Saudi Arabia lands are considered the main source of recharging these basins, and the surface water direction are from the south-southwest to the north-east (towards the Euphrates River) Figure (4).

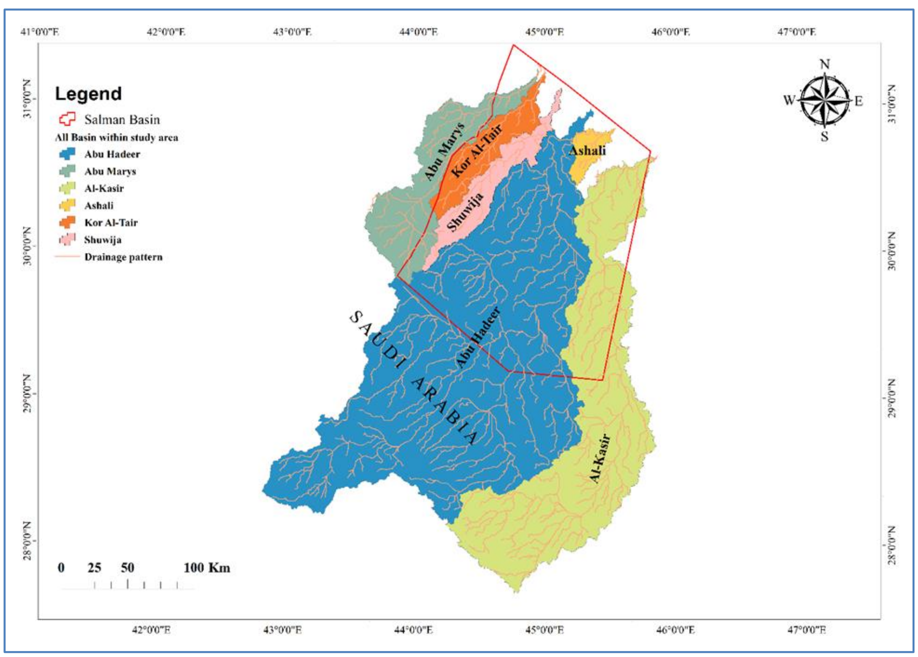

Fig.4. Main groundwater subbasins within Salman basin.

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5. Hydrogeology of the study area

The hydrogeological units are reflecting the principal of geological structures. The spatial distribution and extent of hydrogeological bodies aquifers, aquitards, and their hydrogeological environment are determined by lithological and structural geological conditions. Most hydrogeological investigations are conducted to identify possible sites for the development of sufficient quantities and quality of reasonably good groundwater for a specific purposes [14]. Groundwater is of great importance in areas that suffer from a shortage of surface water sources, a paucity of rainfalls in areas arid and semiarid regions like the southern desert of Iraq. The Salman Basin is one of the most promising areas for agriculture, housing projects, grazing areas where there are many areas encouraging investment in groundwater.

The Karstified Paleogenic carbonate aquifers are characterized by dense fractures and karst cavities that are found in Umm Er Radhuma and Dammam Formations which considered the main aquifers in the study area. It is distinguished by the good quality of water utilized for drinking, domestic, and agricultural purposes. The Dammam Formation is the main groundwater reservoir, composed of movable carbonate rocks such as limestone, dolomite, and dolomitic limestone [11]. The static water levels of 56 groundwater wells were firstly corrected according to the sea level, where, Figure (5) shows that the groundwater flow takes different directions throughout the region depending on geological, topographic and structural features[28], showing the main direction from the southwest to northeast towards the Euphrates River as a discharging area.

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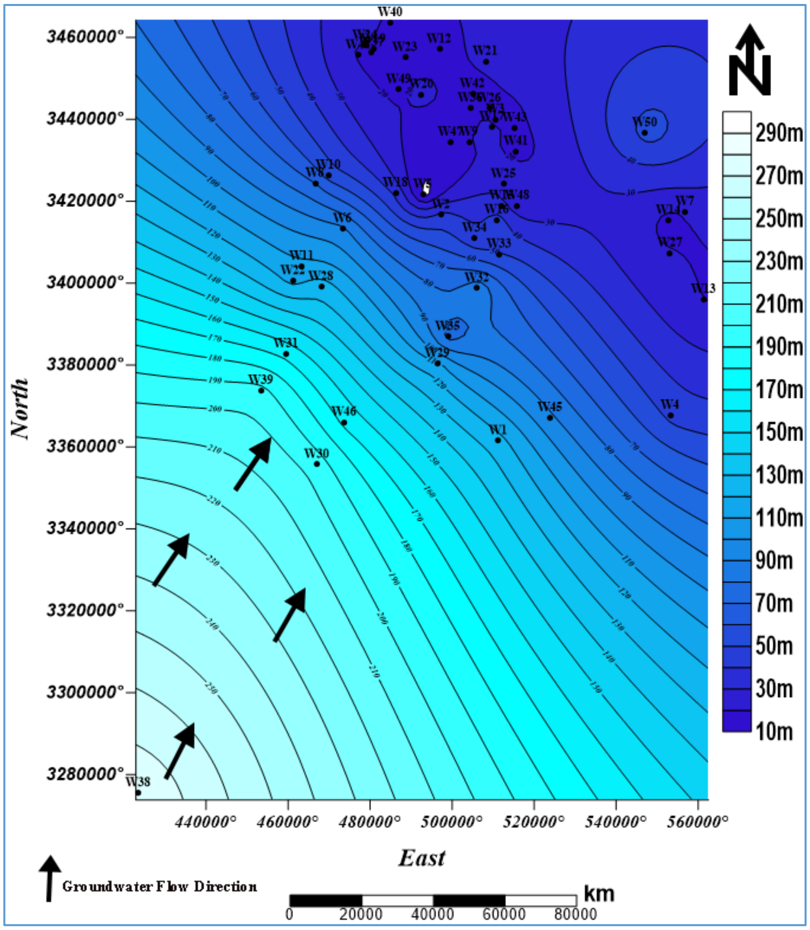

Fig.5. Groundwater levels and flow direction in the studied area.

6. Materials and Methods

• Gravity Method:

Gravity anomalies are caused by differences in the density of materials in the earth. There would be no density contrasts if all of the materials within the earth were laid horizontally and had the same density. The grain density of the particles forming the material, the porosity of the material, and the interstitial fluids within the material are the most important factors controlling density contrasts in different materials[29]. The Bouguer map (Fig. 6) shows major strong positive anomalies (pink) in northern half of the study area with (-24.49 mGal), while there is a strong negative anomaly (blue) in the southern half of the map of study area (-45.93 mGal).

• Data Gravity Acquisition:

The observed Bouguer map is extracted from the Gravity survey was achieved by Iraqi GEOSURV and Iraqi Petroleum Company (IPC) Figure (6). Drift, tide, free-air, Bouguer, latitude, and topography corrections were applied to the measured gravity values using specialized Geosoft software. Bouguer anomaly map was plotted using the corrected gravity values.

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• Gravity Field Separation:

In the present study, residual maps for gravity data were calculated by applying upward continuation (equal to cell size that utilized for gridding of the considered area), and after that subtracted the new grid from the gravity fundamental grid. upward continuation was used to decomposed the Bouguer anomaly into the components related to the relatively shallow depths residual anomalies, and those from deeper sources regional anomalies[30]. The research area's regional, and residual gravity anomaly maps are presented below Figure (7, a and b).

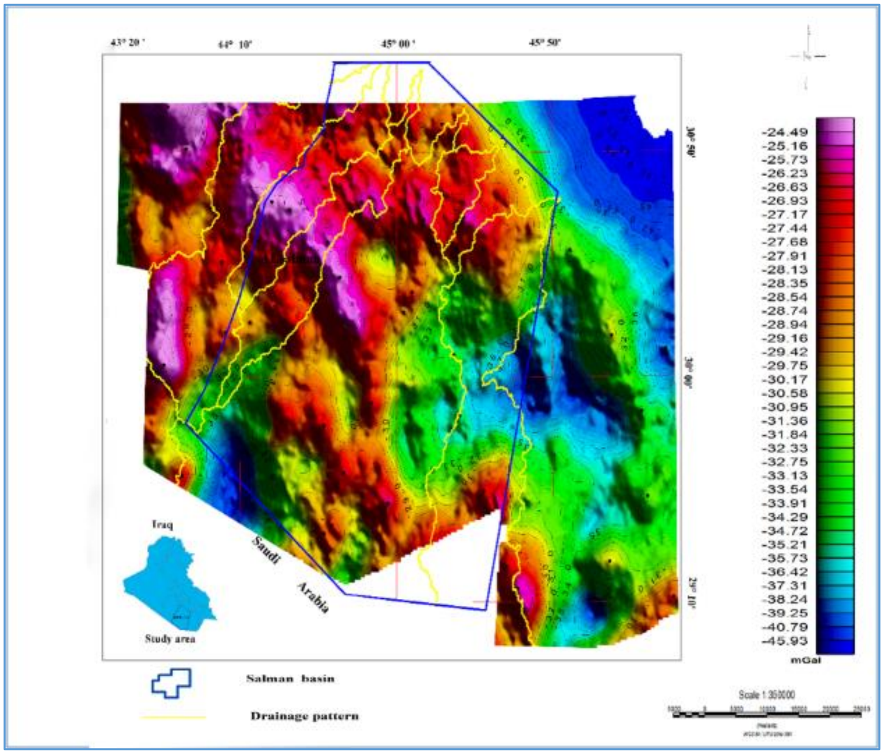

Fig.6. Bouguer Anomaly map of the Salman Basin.

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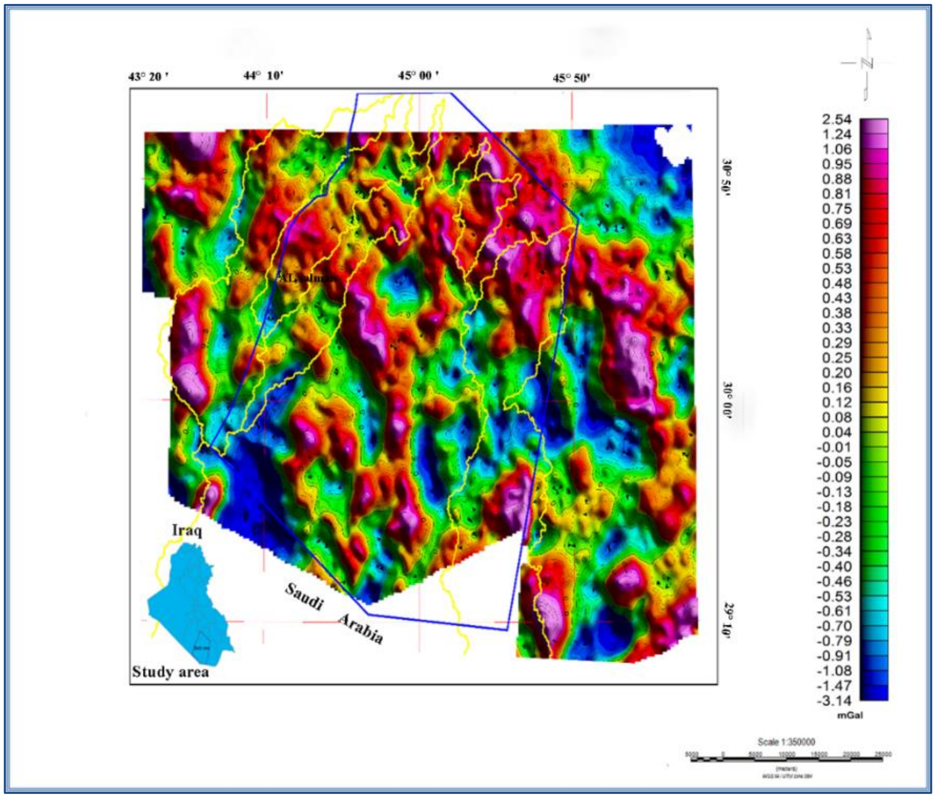

Fig.7: a) Residual map of bouguer Anomaly map - up 3000m of the Salman Basin.

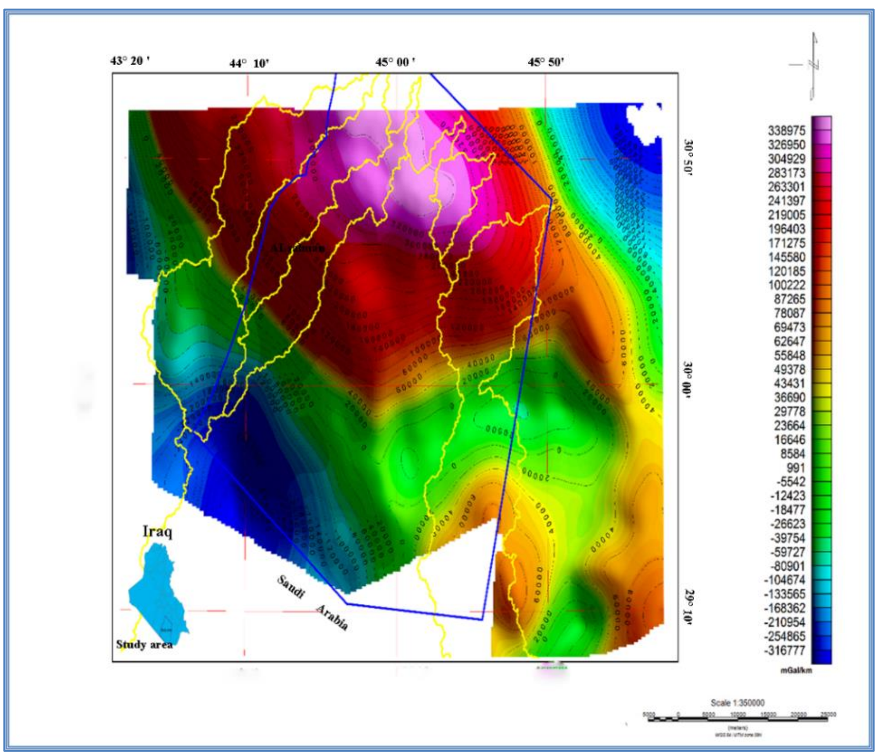

Fig.7: b) Reginal map of bouguer Anomaly map of the Salman Basin.

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• Application filters of Gravity Data

1. Total horizontal derivative (THDR)

The total horizontal derivative and tilt derivative of gravity data are useful tools for identifying the edges and borders of geologic bodies. THDR is frequently used to delineate the borders of features like faults, and contacts. The THDR is highest at the edges and is zero over the body[31]. The standard formula of [32], was used to calculate the THDR of the gravity

$$(THDR)=\sqrt{(\frac{dt}{dx})^2+\left(\frac{dt}{dy}\right)^2}$$

2. Tilt derivative (TDR)

The ratio of the first vertical derivative to the total horizontal derivative of the potential field is known as the tilt derivative. Over the source, the (TDR) is positive close to zero at the edge, and negative outside the source region. It can distinguish sources in low-gradient areas. The approach has a distinct advantage over other edge detectors in that it responds to both shallow and deep sources[31]. The (TDR) technique was also applied to the gravity data using the standard formula of [32] : $(TDR)=\tan^{-1}\left[\frac{VDR}{THDR}\right]$

where (VDR) is the vertical derivative of the gravity data.

7. Results and Discussion

7.1 Gravity Data Interpretation

Gravity data interpretation was used to construct structural element trends that explained the study area. The Bouguer anomaly map (Figure 6) depicts various high and low anomalies based on subsurface rock density variations. The Bouguer anomaly map is separated into two components, regional and residual, which are related to deep and shallow sources, respectively (7, a and b). The residual anomaly map Figure (7a), appeared that the residual values run from (−3.14) to (2.54) mGal. Several positive and negative anomalies were found on the residual grid. The horizontal variety of density within the sedimentary cover due to geological structure is reflected in these anomalies. The negative anomaly near Saudi Arabia border is very clear, with the value less than (−3.14) m Gal Figure (7a). The main negative anomaly observed on Figure (7a), are attributed probably to basin (graben) or sediments mixed with salt while the maxima may represent horst. So, since no apparent evidence of any tectonic feature that could explain the observed gravity anomalies, all these negative anomalies will, may be attributed to subsurface grabens besides that the local small negative features may related with karst feature that is very common in the study area due to geology mentioned in geologic study that such those observed on the Dammam Formation as those shown by [20]. The karst feature with the expected density contrast would have to be of appreciable lateral and vertical extents to satisfy the near surface negative gravity anomalies.

The regional gravity anomaly outline uncovered some positive and negative closures, have trending in NE and NW in the center of the study area near AL-Salman and AL- Shawiya towns, and show the main negative anomaly has the direction of SW and SE near the Saudi Arabia border Figure (7b), this map should reflect the effects of the basement or directly above the Basement.

7.2 Lineament map

The irregular earth features that may be identified on the ground are known as lineaments. These features indicate both the surface and underlying structural features. Lineaments are subsurface faults, contacts, and fractures that influence the occurrence of groundwater acting as canals and reservoirs[33]. The Centre for Exploration Targeting (CET) Grid GX extension was developed by the University of Western Australia [34]. The present study, we used (CET) to find any fractures, contact or faults that may occur within the study area, as well as to show all of the Salman Basin lineaments. The data processing was carried out by using the OASIS Montaj ™ Data Processing and Analysis System [35]. since the existence of lineaments usually indicates a permeable zone, the density of lineaments in an area might eventually reveal the groundwater potential. Groundwater potential zones benefit from areas with a high lineament density[36]. The present study area shows that, there is the relationship between the occurrence of groundwater and fracture traces for carbonate aquifers is often cited, and in particular that lineaments are underlain by zones of localized weathering and increased permeability and secondary porosity. In many instances, the recharged water from the surface through fractures, i.e., recognized lineaments may flow along the bedding planes of rocks or along the faults or karstic cavities. Since the Miocene time, surface running water and water percolating through subsurface rocks have generated solution hallows and cavities of all sizes and shapes at various depths [9].

Results of gravity data delineate the structural (faults or contacts) that are deduced from different filters such as: Tilt derivative (TDR), Total horizontal derivative (THD), and Analytic signal (AS). filters, which exhibit main trends such as (NW-NE and NS-EW).

In the map of the TDR zero contour values are close to the edges of source body. many N–S and its conjugated E-W trends are shown in Figure (8, a, and b). Moreover, the same is true for the trends of NE–SW and NW-SE, Figure (8, a, and b). A maximum in TDR is located usually above the source body. In AS and THD peaks located close the edges of causative body, at the all-study area, especially the areas close to Salman, Shawiya, Takhadeed, Ansab, and Amgar. So many normal faults separated between grabens (blue color) and horst Figure (8, c, d, e and f).

According to Jassim and Gof (2006), the study area is located between several major lineaments. The lineaments trends in the study area which shows different contact, fault elements of different directions such as NW-NE trend parallel to trend Takhadid-Qurna Fault Zone (Transversal System); NE-SW is parallel to the Euphrates fault Zone (Najd Fault System) and the Tar Al Jil Fault Zone (Najd Fault System). The new lineaments were discovered using the CET grid analysis are visible as fault or contact Figure (8, a, b, c, d, e and f). Also, in AS the areas with blue color represent low amplitudes and/or deeper rocks sources Figure (8, e, and f), whereas the areas with purple color show relatively high-density variations of subsurface rocks and/or arising from basement intrusion at relatively low depths.

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In this study many normal faults and contacts were extracted which is very important for the tectonic study, and no direct relation between the lineaments and the drainage pattern, so it is believed that the trends of valleys are controlled by the slop of the area and probably the karst feature which is prominent in are in concerned Figure (9, a, and b).

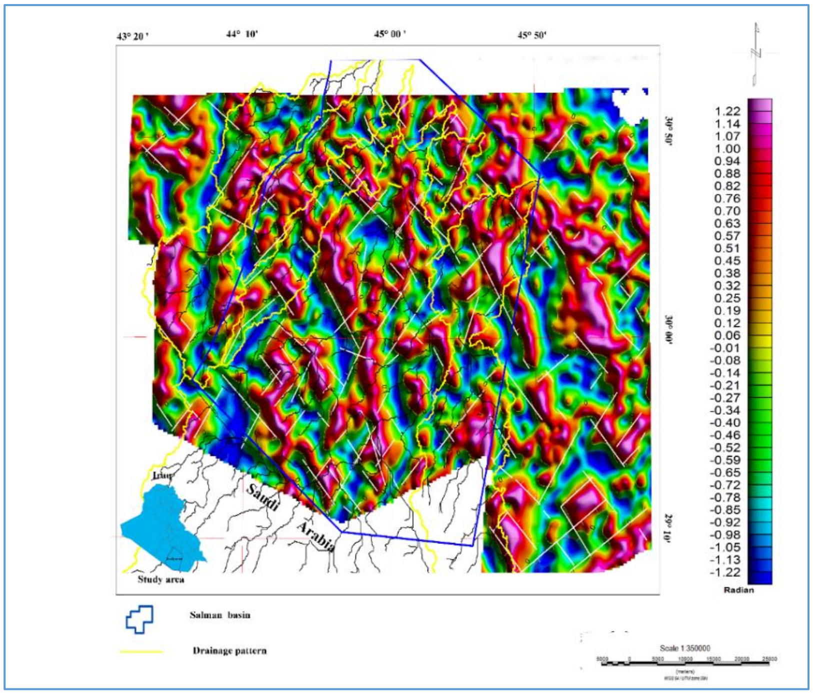

Fig.8, a) Tilt derivative of Bouguer Anomaly map shows NW and NE lineaments trends of the Salman Basin.

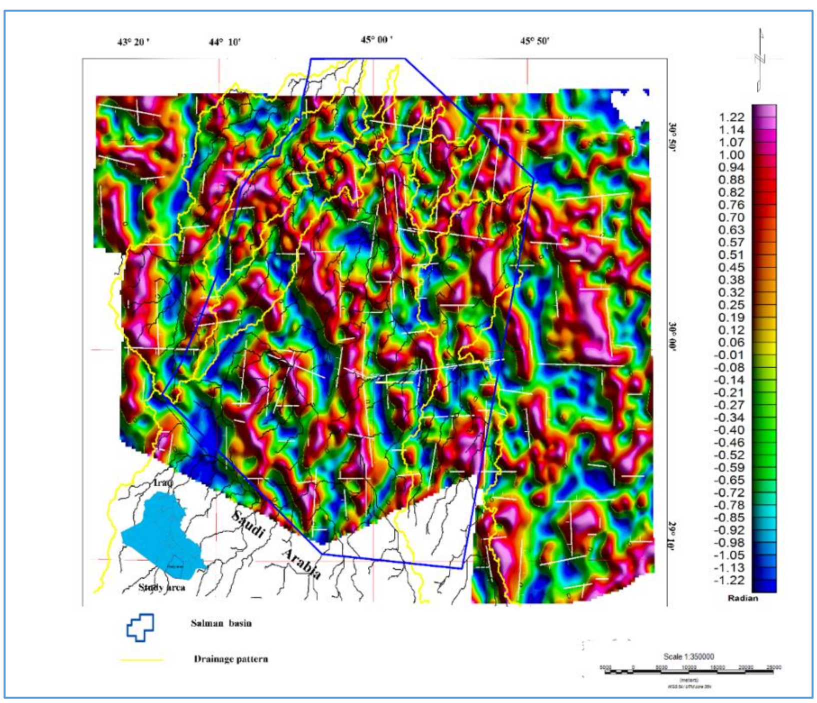

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Fig.8, b) Tilt derivative of Bouguer Anomaly map shows NS and EW lineaments trends of the Salman Basin.

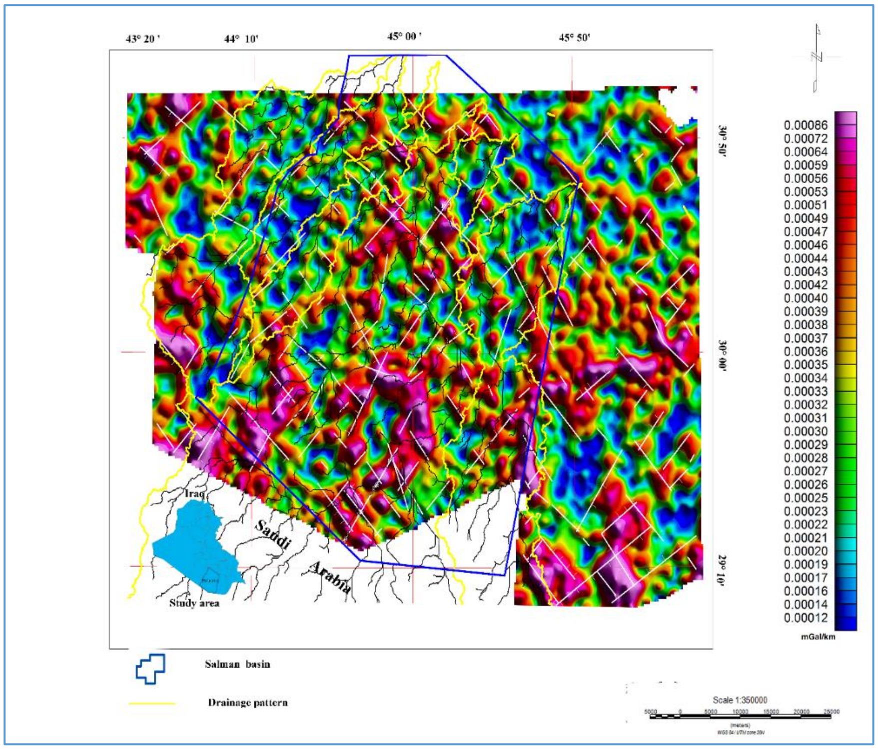

Fig.8, c) Analytic signal of Bouguer Anomaly map shows NW and NE lineaments trends of the Salman Basin.

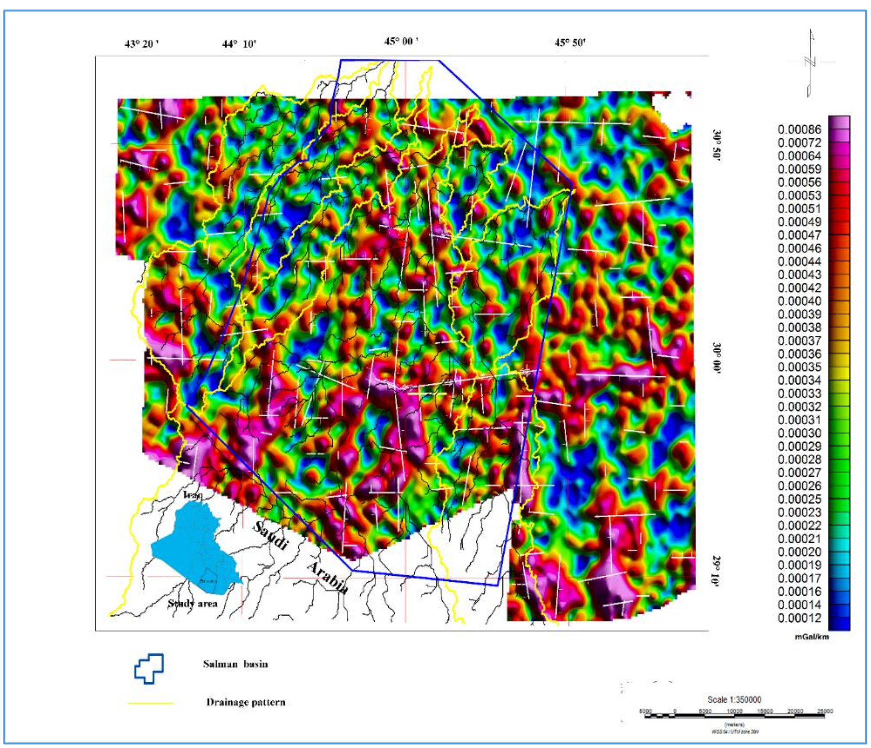

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Fig.8, d) Analytic signal of Bouguer Anomaly map shows NS and EW lineaments trends of the Salman Basin.

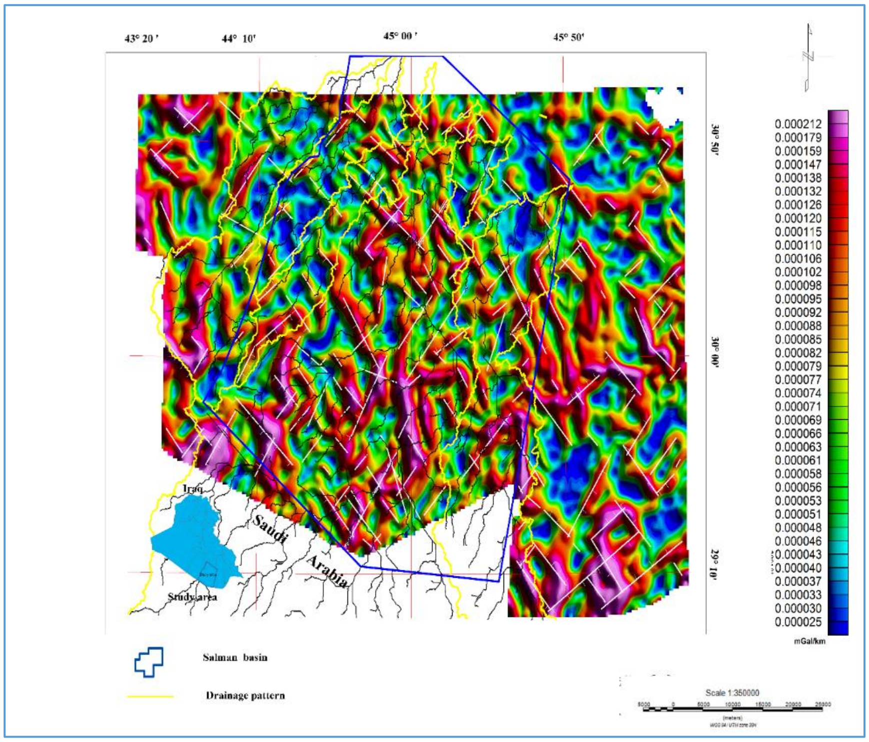

Fig.8, e) Total horizontal derivative of Bouguer Anomaly map shows NW and NE lineaments trends of the Salman Basin.

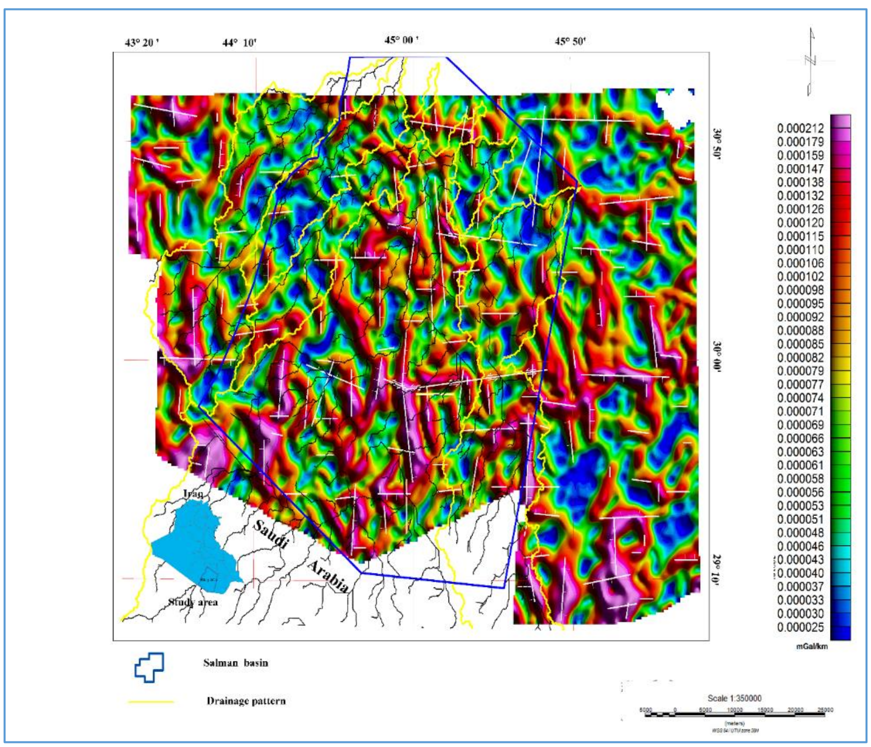

Fig.8, f) Total horizontal derivative of Bouguer Anomaly map shows NS and EW lineaments trends of the Salman Basin.

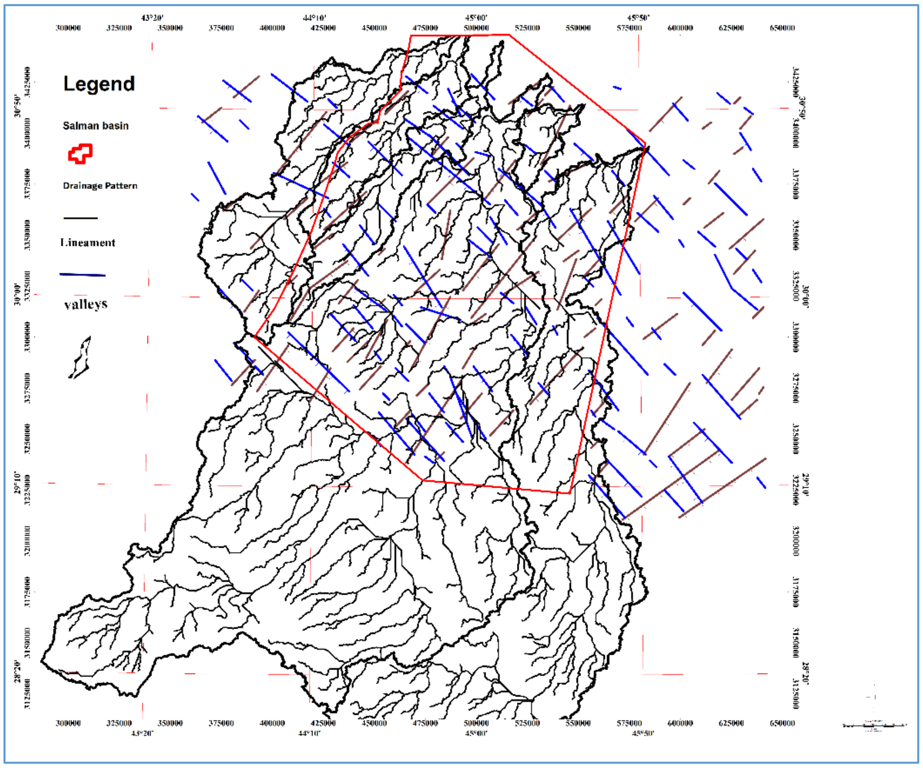

Fig.9, a) Study area map shows relationship between NW and NE lineaments trends, drainage pattern, and main valleys.

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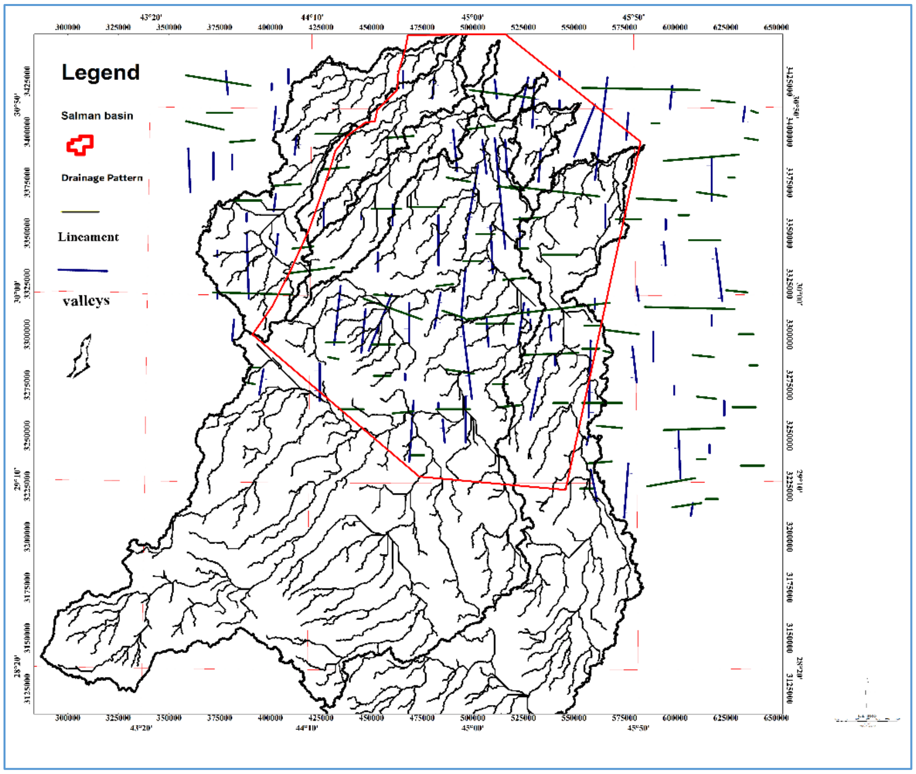

Fig.9, b) Study area map shows relationship between NS and EW lineaments trends, drainage pattern, and main valleys.

8. Conclusions

1-The subsurface geology of the study area consists of an almost horizontal succession of solution limestone and evaporated rocks of the Rus Formation, Umm Er Radhuma Formation, and Dammam Formation. The areas where the limestone is marked are characterized by sinkholes, which were formed due to dissolution by water gives a more distinctive type of caves.

2- The Bouguer gravity map reflects mainly the structures that lie above the basement, i.e., sedimentary cover anomalies and these anomalies complete those of the outside the present study area.

3-The study area contains a high gravity gradient which will be related to reflect the occurrence of a depression filled, most of these features seem to be of small lateral extent as compared to the suggested proposed basin filled with sediments contain salt.

4- Detailed interpretations of the small local residual anomalies have indicated to be near subsurface to satisfy the observed such anomalies and this will mean that the process of the solution has affected the Dammam Formation in addition to the Rus Formation, at a depth ranging from 100 m to 450 m [9].

5-The negative gravity anomaly (blue color) is complementary to the negative anomaly of the studied area. This anomaly is surrounded by a high gravity gradient that may be related to the

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presence of faults: Takhadeed Suq Al-Shoyokh Amara fault, and Ansab- Al-Busaya- Qurna Fault located within and East side of the study area.

6-There are two sets of lineaments in the present region: the first set is taken the NW-NE direction perpendicular to the extensional structures, whereas, the second set have the NS-EW direction. Areas with high lineament density have a chance of highest permeability, which means they have a higher possibility of gathering groundwater, especially the location of lineaments intersections, Figure 9, a, b shows that there is no relationship between different lineaments trends and the drainage pattern.

7- The karst feature which is prominent in are in concerned in study area, and the main valleys extending from the Saudi lands to the study area are considered a source of Groundwater Gathering and recharge formations, especially the Umm Er Radhuma Formation, Dammam Formation and Rus Formation.

Conflict of interests.

There are non-conflicts of interest.

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