The Evidences of Neotectonics Activations by using geomorphological Characteristics and Remote Sensing, and use that in Exploration of Oil and Gas: A Case Study in Al-Amghr Valley – Southern Desert of Iraq

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Abstract

The study area is located in the extreme south-west of Iraq, and it forms part of the southern desert of Iraq. The region shows important evidence that confirms the occurrence of Neotectonics activations. The most significant evidence is the change of the large valleys towards its major streams as seen in the river course of Wadi Al-Amghr, which mainstream is ranked 7 according to the mathematical analysis of the ArcGIS program. In the current study, geological, geomorphological, topographic, and hydrological data are used in addition to the remote sensing data and fieldwork. The study results show that the original course of Wadi Al-Amghr is like the course of the rest of the desert valleys in the region (SW - NE) before recent tectonic activities. It is observed that the recent tectonic activation affected Al-Amghr Valley, which changes its stream direction (to the east and west) as its mainstream is divided into two streams when entering Iraq by over 10 kilometers.

It is expected that the area is subject to recent tectonic ground uplifting to form a gigantic trap (anticline fold) for oil and gas. Exploration and investigation of various natural resources using remote sensing techniques are an important topic in our time, especially if it leads to the exploration of oil and natural gas, which in turn develops these areas.

Keywords: Geomorphology, Neotectonics, Remote Sensing, Oil & Gas, Wadi Al-Amghr, Morphotectonic, Southern Desert of Iraq.

الكشفُ عن أدلة التنشيط النيوتكتوني بإستخدام الخصائص الجيومورفولوجية والإستشعار عن بعد، واستخدامها في التنقيب عن النفط والغاز: دراسة لوادي الأمغر - الصحراء الجنوبية للعُراق

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الملخص

تقع منطقة الدراسة أقصى جنوب غرب العراق، وهي جزء من صحراء العراق الجنوبية. تظهر المنطقة أدلة مهمة تؤكد حدوث عمليات تنشيط تكتونية حديثة – **Neotectonics**. الدليل الأكثر أهمية هنا، هو عملية متابعة تغيير الوديان الكبيرة لإتجاهات مجاريها الرئيسة كما يظهر في حالة مجرى وادي الأمغر، والذي تم تصنيفه في المرتبة السابعة وفقًا للتحليل الرياضي لبرنامج ArcGIS. في الدراسة الحالية ، تم استخدام البيانات الجيولوجية ، الجيومورفولوجية، الطبوغرافية والهيدرولوجية بالإضافة إلى بيانات الاستشعار عن بعد والعمل الميداني لتتبع أدلة حدوث عمليات التنشيط التكتوني الحديث.

أظهرت نتائج الدراسة أن المسار الأصلي لوادي الأمغر يشبه مجرى بقية الوديان الصحراوية في المنطقة (جنوب – شمال شرق) قبل حدوث الأنشطة التكتونية الأخيرة. لذلك، يُلاحظ أن التنشيط التكتوني الأخير قد أثر على وادي الأمغر ، مما أضطره لتغيير إتجاه مجراه (إلى الشرق والغرب) حيث ينقسم مجراه الرئيسي على مجريين رئيسين بعد دخوله العُراق بأكثر من ١٠ كيلومترات داخل العمق العُراقي.

نتيجةً للتنشيط التكتوني الحديث في المنطقة، فمن المتوقع أن تكون هذه المنطقة قد خضعت لعمليات الرفع الأرضي التكتوني الأخير مما يمكن ان يتسبب بتشكيل مصيدة عملاقة (طية منحنية) للنفط والغاز. كذلك، يُعدُ التنقيب عن الموارد الطبيعية المختلفة وإستكشافها بإستخدام تقنيات الإستشعار عن بعد موضوعًا مهمًا في عصرنا الحالي، خاصة إذا كان يؤدي إلى إستكشاف النفط والغاز الطبيعي ، والذي بدوره يطور هذه المناطق إقتصادياً.

الكلمات المفتاحية: الجيومورفولوجيا ، التنشيط التكتوني الحديث ، الإستشعار عن بعد، النفط والغاز، وادي الأمغر ، مورفوتكتونيك ، الصحراء الجنوبية للعُراق.

1. Introduction:

This study focuses on the role of recent tectonic movements (Neotectonics) and their geomorphological impacts on the surface of the earth (i.e. Morpho-Neotectonic effects), and the possibility of their control on the localization of various natural resources (e.g. water resources, hydrocarbons).

Neotectonics are known as the recent earth movements and the accompanying deformations that occur mostly in slow and graduwaysways during recent geological ages. "Neotectonic movements took place in the second half of the Tertiary and Quaternary periods; exactly from the Oligocene age (**Obruchev, 1948**; **Vita-Finzi, 1986; Hancock, 1988**). In Iraq, Neotectonic movements are recorded in the Miocene sedimentary cover. These movements are crucially important in forming recent relief to fully explain the main topographic features throughout the globe (**Obruchev, 1948**).

Morphotectonics (from Ancient Greek: μορφή, morphḗ, "form"; and τεκτονικός, tektonikos, "pertaining to building" (**Online Etymology Dictionary**), or tectonic geomorphology, is a branch of geomorphology that studies how landforms are shaped or affected by tectonic activity (**Doornkamp, 1986**). Morphotectonics based on multidisciplinary studies involving geology, seismology, physical geography, climatology, geochronology, and geodesy (**Burbank, 2012).**

The term Morpho-Neotectonics refers to the geomorphology of recent tectonic activation (Neotectonics). In other words, they are geomorphological ground forms and geological structures that arise and are affected by the recent tectonic movements, where their effects are left clearly on the surface the of earth and its shapes in addition to the various sub-layers that appear during the recent geological ages (from Miocene to Holocene) (**Al-Gurairy, ,Naravas and Usova, 2018**). Because they are short-lived and recent in their formation, it is difficult to distinguish them via direct observation a during person's life except certain such cases (as the phenomenon of rejuvenation of the Euphrates River between Shannafia and Samawa at the beginning of the last century (**Al-Gurairy, 2000**). But it can be evaluated and recorded through changes in the geomorphological features on the earth surface.

These tectonics may be a reactivation of previous tectonic manifestations such as the reactivation of domes, anticline folds, sub-surface structures, the occurrence of a small displacement on faults leaving simple surface effects, and the effects of removing the blocks on the sides of the old faults. It might be that rivers and their surface networks (including desert valleys) are the best reflectors of these tectonic changes due to their continuous dynamic and the noticeable effects on their flow path, change in their slope, and the sudden change in topography caused by the simplest movements. The interception of the riverbed to buried faults appears on the surface as a result of recent tectonic activations.

The most important question here is whether there are recent tectonic activation processes in the region recently or not?

Do the recent tectonic (Neotectonics) activations have a direct impact on the geomorphology - Morphotectonic of Al-Amghr Valley? Does it cause a change in its flow in the region?

Other essential questions arise about whether there is a possibility to explore mineral-hydrocarbon resources (oil and gas) in this region through the use of recent tectonic activation that can be available in the region with the help of remote sensing?

The presented geomorphological behavior of Wadi Al-Amghr in the Southern Desert is a natural reflection of the Morpho-Neotectonics in this region.

1.1. location of Study area:

Wadi Al-Amghr is located in the southeastern part of the Iraqi southern desert (**Figure 1 A, B**), it is a large valley that originally branched from Wadi Al-Batin in the Kingdom of Saudi Arabia under the name (Wadi Fledge) (**Figure 1C**), then enters Iraq through the south-southeast part of the southern Iraqi desert, which named here as (Wadi Al-Amghr).

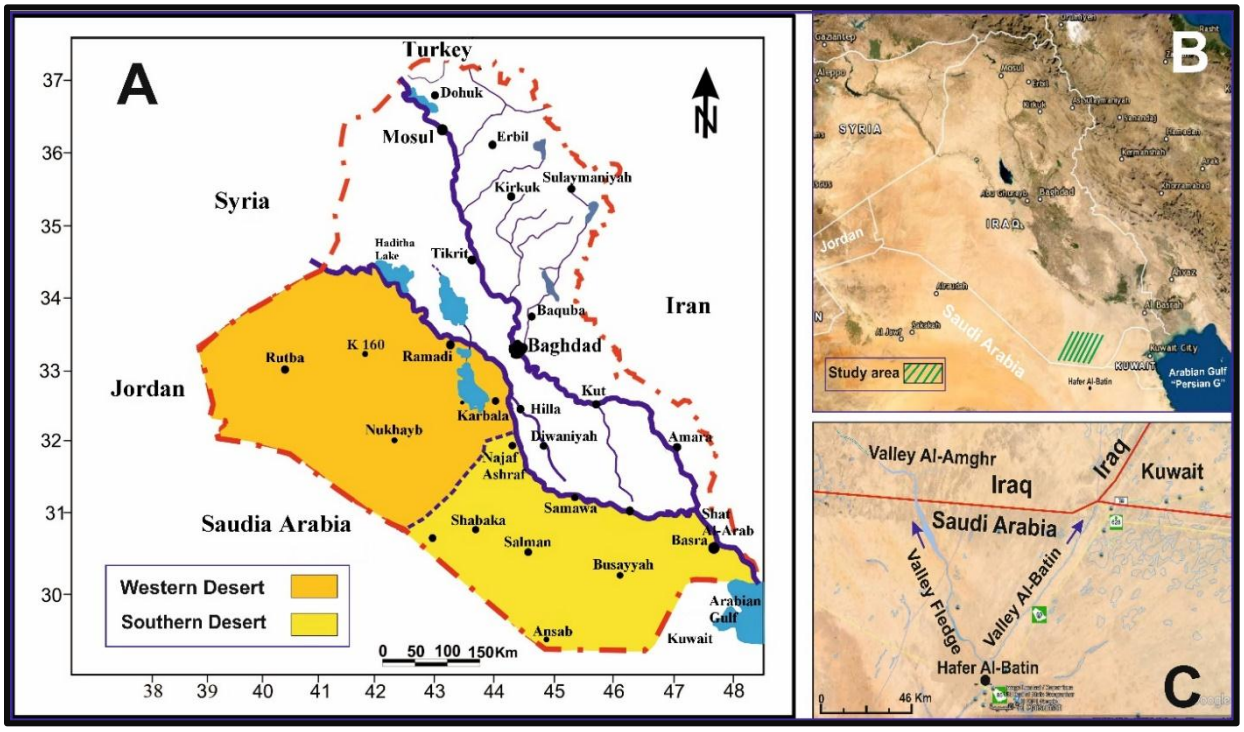

Figure (1) Location of the study area

2. Geological Setting

Various geological aspects are discussed in the following sections focusing on those applied to the evolution of the Valley Al-Amghr. Moreover, the information presented is based primarily on the best data available.

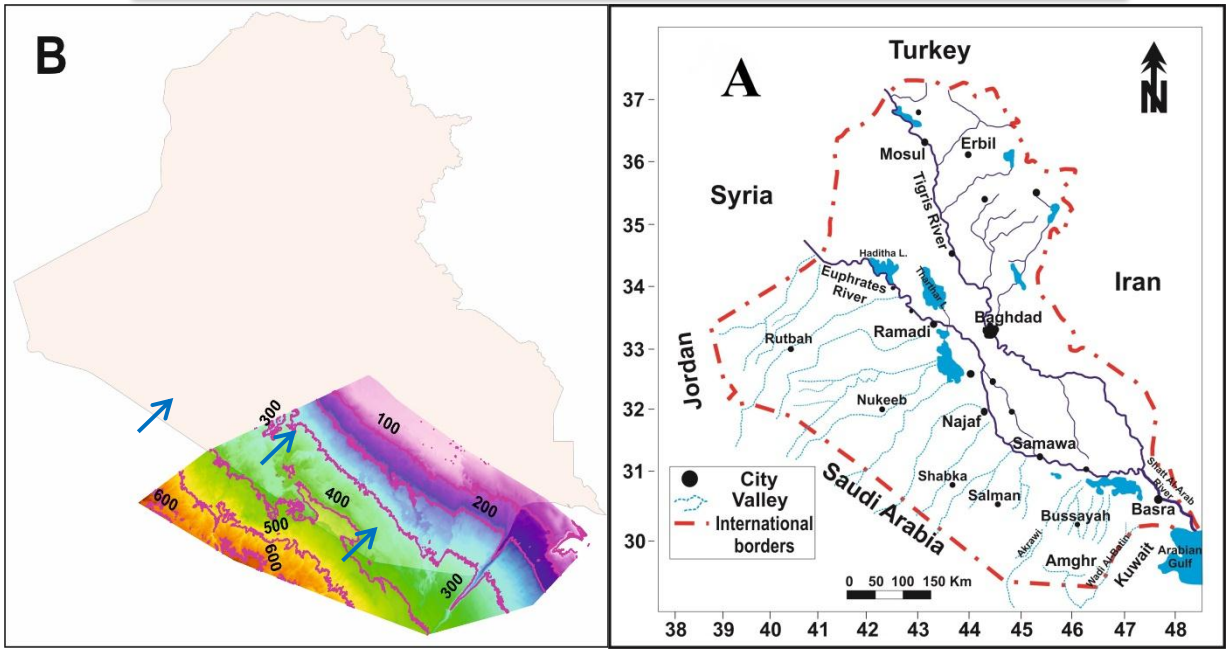

***Figure (2) A**: The direction of the flow of desert valleys in the western and southern desert from the southwest towards the northeast, where most of them flow into the course of the Euphrates River (**Ma'ala (b), 2009; Sissakian and Mohammed., 2007**)*

***B:** The slope of the land in the southern desert (southwest-northeast) with an illustration of contour lines (ground elevations) in it (made using DEM in the study area and by ArcGIS software*).

2.1. Tectonic setting and structural evolution:

In the Southern Desert of Iraq, the NW-SE and NE-SW trending is the Precambrian fractured continental basement complex that covered by relatively thin Phanerozoic sediments, which are part of the northern Arabian Platform. Generally, this platform is divided into two parts; the first one is called the stable plate that represents the Southern and Western Desert of Iraq. The second one is unstable and situated to the east and represents the Mesopotamian plains. It does not mean that one of these parts has no tectonic movements, but rather it is less frequent when compared to unstable part. But, Euphrates Fault Zone (extensions of Abu Jir Fault system) serves as the dividing line between the two sections of the platform (**Fig.3 A**).

In the Southern Desert, the structure and evolution of Paleozoic series is still a mystery. In the Campanian-Maastrichtian, the Mesozoic cover is characterized by substantial carbonate deposition with interspersed clastic episodes and distinguished by few time gaps. However, the Cenozoic sequence shows a gradual retreat of the sea and final transition to continental conditions (**Ma'ala Khaldoun. A. (a), 2009**).

Generally, the main structural element in the Southern Desert is Safawi Arch, which is initiated to form in the Late Triassic - Early Jurassic. The sedimentation pattern through most of the Mesozoic era represents a reflection of a fluctuating sea level and periodical movements of Safawi Arch (**Fig.3 B**). During the Late Oligocene and Miocene periods, the main tectonic events were periodic uplift and down thrust along the southeastern slope of Safawi Arch, which reactivated the Al-Batin fault system and led to the development of the Dibdibba basin that ended by a restricted

right-lateral strike-slip movement on the Euphrates Fault Zone in the Pliocene–Pleistocene (**Ma'ala Khaldoun. A. (a), 2009**).

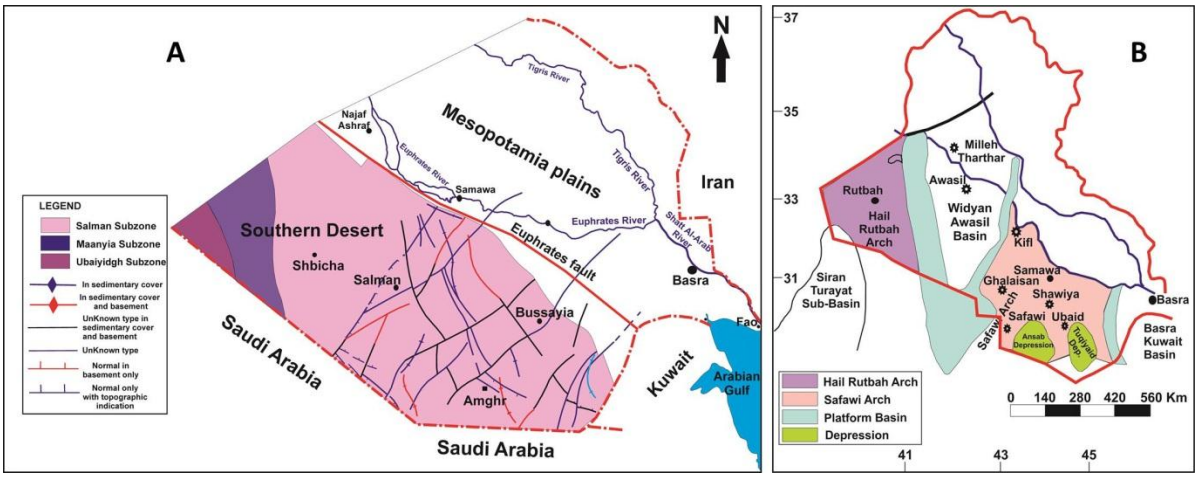

Figure (3) A- Tectonic map of Al-Amghr region (**Al-Kadhimi et al., 1996**); B- Safawi Arch (**Henson1951**)

Although the Southern Desert tectonic and structural evolution as being part of the Stable Platform of the Arabian Plate, it is still continuous. The geological, geophysical, and deep drilling data have shown that the Stable Platform is divided up into local basins and uplifts controlled by deep-seated block faulting in the basement rocks (**Fouad, 2007**). The tectonic pattern here is complex because it results from the interplay of differential movement on the fault systems, which are oriented predominately in NW-SE, and N-S directions. (**Fig. 3 A**). Furthermore, it is worthy to mention that the simple inclination of the rock layers towards the northeast is the main tectonic characteristic in this territory. (**Al-Mutawqi et al., 2021**)

The Arabian Peninsula's accretion and cratonization during the Proterozoic eon (950 to 640 Ma) and subsequent intercontinental collapse and Najd strike-slip faulting system during the Latest Proterozoic - Earliest Paleozoic era (620 to 550 Ma) printed two key patterns of weakness within the continental basement. Also, there are lines of weakness that are N-S and NW-SE trending (**Fouad, 2007**). The position and style of some later Phanerozoic deformations are controlled by these lines of weakness. According to **Buday and Jassim (1987), Jassim and Goff (2006),** the Southern Desert is marked by a relatively thick Mesozoic Tertiary cover, and the thickness of the Infracambrian-Paleozoic series is greatly reduced, but the Oligocene deposits vanish in Southern Desert of Iraq.

2.2. Geomorphology:

The study reveals that the present surface of the Southern Desert is attributed to a rejuvenated plateau, which arises as a result of the destruction and construction that processes occurred during two continental phases. The older plateau was created by the first phase, which began after the Oligocene Uplift. The beginning of subterranean hollows and caves, as well as prevailing denudation processes in a semiarid environment characterize this era. The Pliocene and Quaternary Periods created the younger plateau in the second phase began after the last Alpine movements. (**Ma'ala Khaldoun A. (b), 2009**).

In respect to climate, there are certain variations between wet–arid and semiarid, which lead to denudation in some areas and deposition in others. Therefore, it formed Twenty-four landform assemblages that are distributed through three physiographic divisions and seven morphogenetic classes of varying origins that are distributed on three physiographic units called: Al-Hijara, Al-Dibdibba, and Al Hamada plains (large areas covered by sandy limestone sheets). Each unit has specific landform assemblages, which reflects the effect of the structure, lithology, and climate (**Ma'ala Khaldoun A. (b), 2009, AL-Gurairy,2019)**

Moreover, during the Pleistocene and early Holocene, the exterior portion of the younger plateau was depressed due to the effects of the erosional mechanism along the Euphrates Fault Zone. It later changes to a foot basin due to the availability of clastic sediment from the elevated areas of the plateau. Furthermore, the polygenetic accumulations by evaporation, Aeolian, estuary, and floods of Euphrates River increase the situation. The geomorphology of the "Southern Desert" is controlled by three major aspects: climate, lithology, and drainage pattern of its desert valleys **(Al-Abdan & Al-Gurairy, 2017)** in adition to the role and importance of the relationship of tectonic activation to the development of the hydrographic network of river basins and its correlation with the major relief structure. Therefore, it is possible to form streams parallel to high-altitude lines and consistent, transversal, and subsequent streams (**Grecu et al., 2021**).

According to data collected by the Iraqi Meteorological Organization (1941–2000), the current climate is characterized by mean annual temperature of (24 °C to 26 °C), mean annual of evaporation of 4500 mm, and heavy precipitation that occurs sporadically for a short period of time during winter months, where the mean annual of rainfall ranges between 75 – 100 mm. The study area is characterized by a desert semiarid climate (**Ma'ala Khaldoun A. (b), 2009)**.

In areas, where the Dammam formation (Middle-Eocene) is exposed (**fig. 4**), the formed drainage pattern has different density and distribution. The density is low due to karst features and the creation of immature valleys. The Ghar and Nfayil formations (Lower and Middle Miocene, part of the study area) are exposed to the drainage pattern, which is well-developed is parallel and/or dendritic type. **(Jassim and Al-Jiburi, 2009, Ma'ala Khaldoun A. (b), 2009, Deikran, 1995)**.

The Structural – Denudation forms, like a plateau and tectonic depressions as Samawa Saline, Slabiat Depressions ... etc., are formed by strike-slip movement along the Euphrates Fault Zone, and Al-Salman depression (**Ma'ala Khaldoun A. (b), 2009**). Generally, there are some geomorphological features in the area represented by the depressions, and there are two hypotheses to explain the presence of these depressions. The first one is likely to be formed by recent tectonic processes. The second one is likely to be formed by the dissolution of the lower formations, especially the Rus Formation. Based on that, there are no clear geological structures, while the hydraulic properties follow or relate to the nature of the terrain. (**Jassim and Goff, 2006; Al-Mutawqi et al., 2021**).

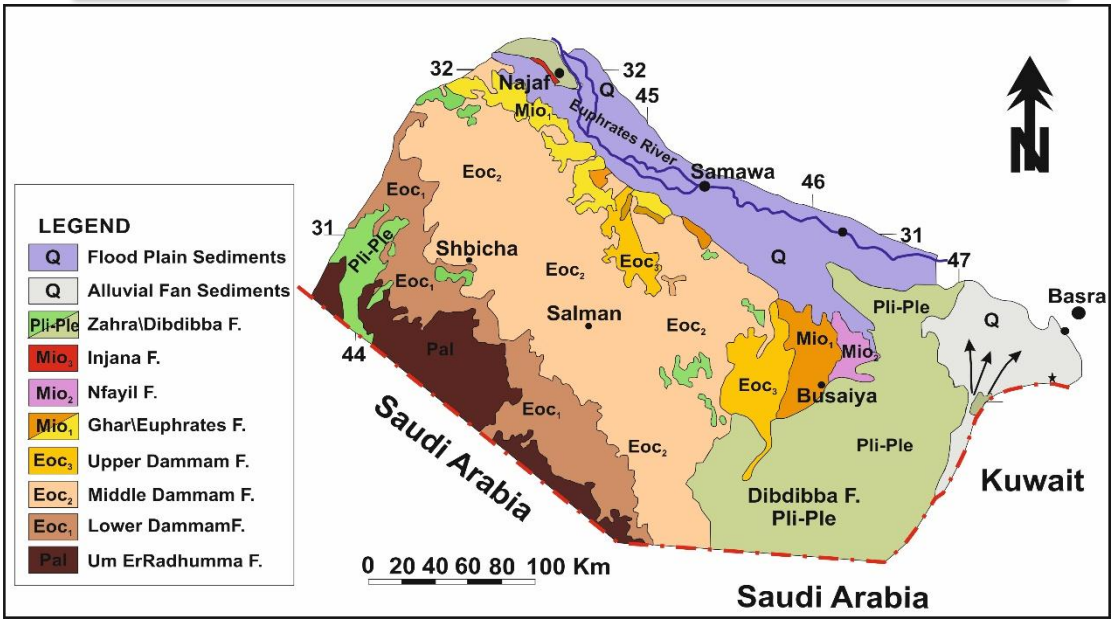

Figure (4) Geological map of the study area (after Sissakian 2000)

The most prominent geomorphological forms within the study area are multiple hills (**figure 5A**), single hills, Mesa, desert plains, desert valleys streams, terraces, sand dunes, karst phenomena, cavities, and small desert basins as known Al-Faidha (**fig. 5B**).

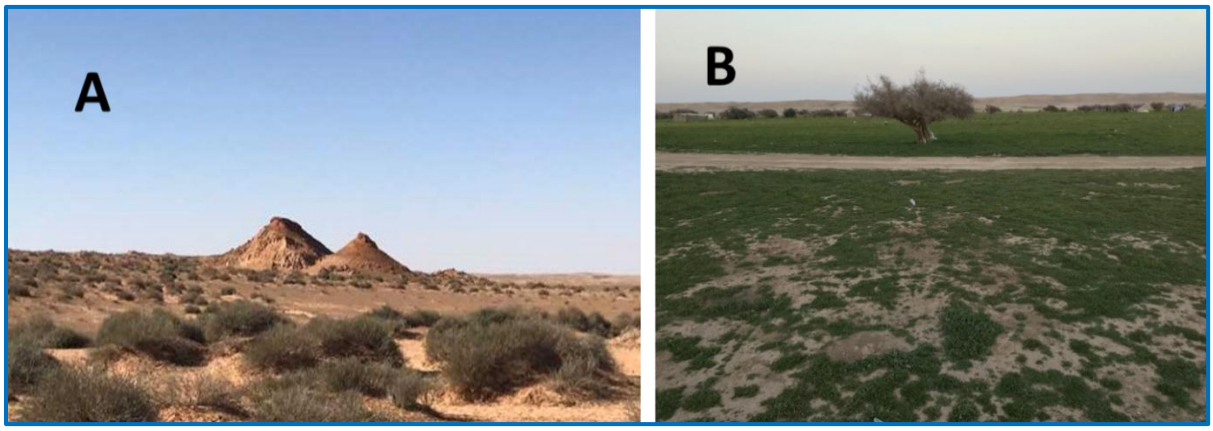

Figure 5 Geomorphological forms (A- Hills & B- Faidha) in the study area

The study area has forms of Solutions Origin like Sinkholes and Karst Valleys while the units of Aeolian origin comprise Dibdibba Sand Sheets and Nebkhas. The Units of Fluvial Origin comprise Flood Plain, Fluvial Plain, and Alluvial Fans **(**Al-Abdan & Al-Gurairy, 2017). Most of the desert forms are developed by paleo-surface hydrological processes, which are modified by wind in the latter phase. (Al-Dousari et al., 2009).

3. Materials and methods

3.1. Fieldwork

The fieldwork in the Al-Amghr area was carried out in March 2021. It was done with the escort of local guides and inhabitants (Bedouin Arabs) of the region, because of the presence of remnants of the 1991 previous war on the one hand, and also because of the presence of predators in the area. Several sites were examined in detail for geomorphological, geological, and structural features and compared with previous studies of the area and results of the previously analyzed satellite imagery. The Global Positioning System (GPS) [Garmin (eTrex 3)] model in spatial error 1 m, was used to determine the elevation for many sites of the Wadi Al-Amghr water stream and compare them with the preliminary results got from the topographic maps of the area and satellite imagery, Figure (6).

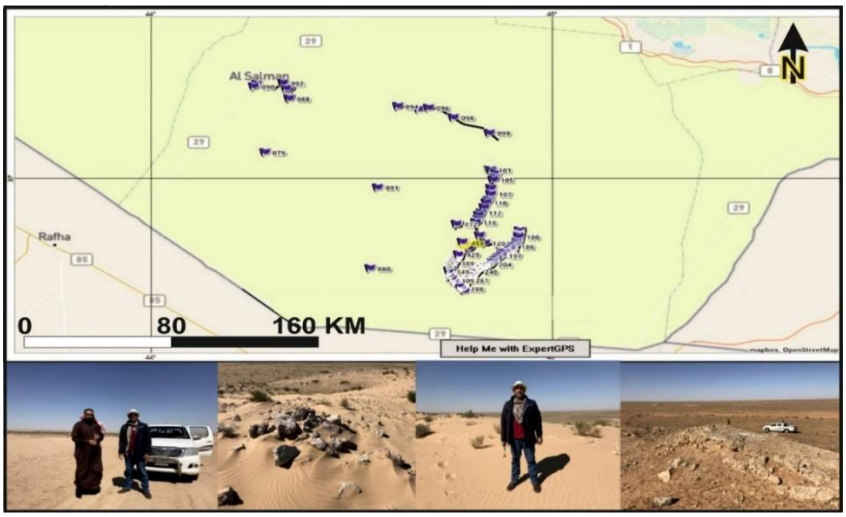

Figure (6) The itinerary and some waypoints of the field study in the southern Iraqi desert

3.2. Remote sensing and geographic information system (GIS) Data

The remote sensing data sets provide the basic information of this study. [Landsat 8, Digital elevation model (DEM), Google Earth view, ArcGIS 10.8 application, and GPS data]. As a result, visual interpretations of the key topographic features and identification of the main geomorphologic units in the study area are achieved using the Shuttle Radar topographic project DEM with Landsat 8. Furthermore, in Arc GIS setting, the relief map derived from SRTM DEM (spatial resolution, 30 m) is combined with Landsat 8 image to extract linear features (faults and/or fractures) in the study region, and ensures the accuracy of the area tectonic map.

The key structural trends in the study area are identified manually to trace the structural lineaments. All collected data (DEM, LC8, geologic maps, topographic maps) are registered to unified projection Universal Transverse Mercator (UTM) zone **38 North with WGS 84** datum in the GIS environment for additional correlation operation. The United States Geological Survey's (USGS) website is used to collect all remote sensing data.

Furthermore, DEM is used to extract the watershed boundaries and drainage network of Wadi Al-Amghr basin, where **D8** flow direction, which represents the eight main directions of the valleys streams - north, east, south, west, northeast, and west, southeast and west algorithm is used in the Arc GIS hydro software.

When we integrate the information got from the area geological maps, and remote sensing data, we are able to compare them with the data of the field study and determine the reasons and time of changing the stream of Al-Amghr valley. It is worth to mention that morphometric analysis of the drainage network with the Horton-Strahler classification allows comparisons of the genesis and dynamics of river segments and the vulnerability of the land to hydro-geomorphological processes. Therefore, it enables us to know and identify the main reasons that lead to recent tectonic activation in this region. It will be possible to employ these results in the process of surface-geomorphological explorations for oil and gas in this region.

3.2.1. Topographic wetness index (TWI)

TWI is firstly introduced by **Beven and Kirkby (1979)** that studies the impact of local topography on runoff flow direction and rainfall accumulation. The following is the equation for calculating the TWI at a given point:

$$\mathbf{TWI = In\ [\ \frac{As}{\tan \beta}\ ]} \qquad \mathbf{(1)}$$

Where, as is the upslope contributing area and β is the topographic slope. TWI values are determined automatically in the Arc GIS setting using the SRTM DEM of the study field. The most important derivatives of the DEM used to calculate TWI fill the DEM, flow direction, flow accumulation, and slope. Also, the factor of flow accumulation is extracted, with a condition of (sensitivity to 500) Figure (7) & (8A, B, C). The researcher uses the conditional equation to set the sensitivity to 500 (value ≥ 500) when deriving desert valleys.

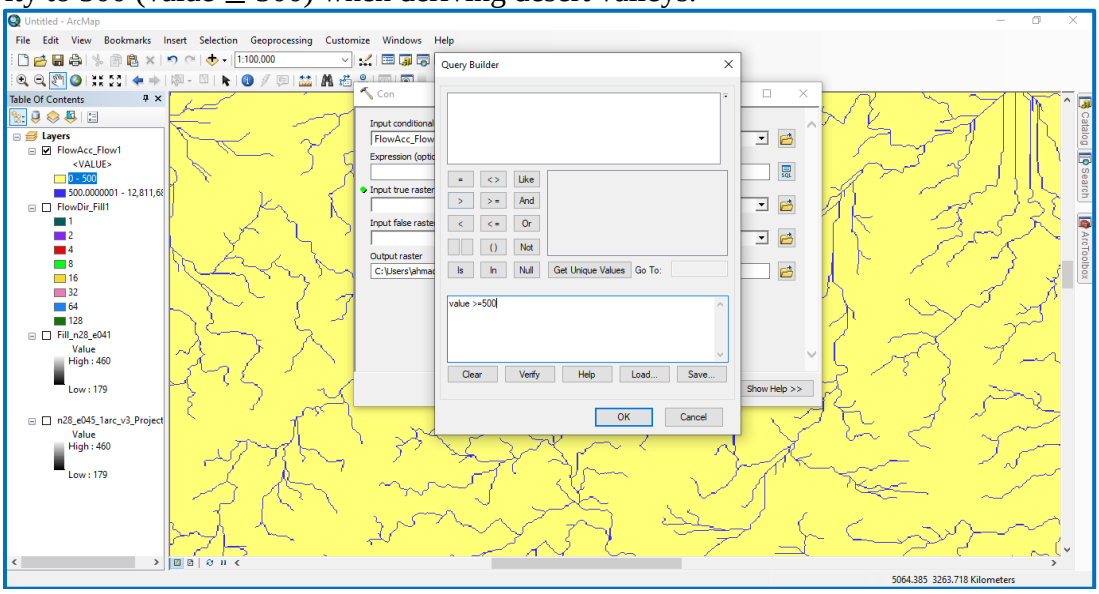

Figure (7) Using the equation value 500 to extract desert valleys in the ArcGIS program

Based on the researcher's personal experience in deriving river valleys in the southern desert of Iraq, it will be better if a sensitivity value between **100 – 50** is used but a **sensitivity of 500** is used for workflow. The stream order process is extracted based on the **Strahler method**, and the file of these river ranks is transformed from Raster to Vector, **figure (8 C)**. As a result, the river basins are extracted for all major valleys in the study area, **figure (8 D)**. They are also transformed from Raster to Vector to facilitate dealing with the ArcGIS program environment. Also, by using the Arc GIS software, the area's slope layer was also built from the DEM **Figure (8)**.

The produced GIS data layer (raster) defines areas with drainage depressions in which water is likely to collect as the end product. Every raster's value is relative to the study area. These layers are transferred from Raster to Victor to identify and control the study area easily.

All these processes are used to get important results, where the ideal course of Al-Amghr valley should be in the study area. To determine the correct answer regarding the conformity (or not) of the current stream of Al-Amghr valley with the ideal course, it should be taken on the ground.

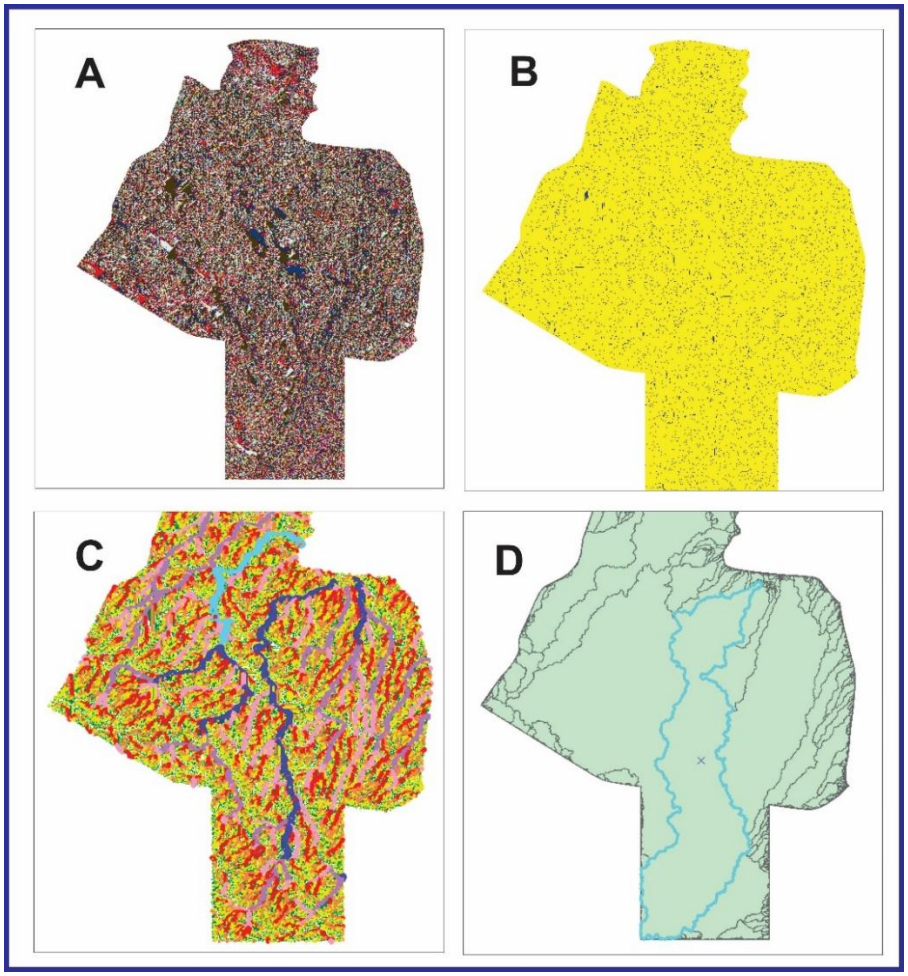

Figure (8) Figure (8) DEM processing by software ArcGIS

3.2.2. Topographic Roughness Index (TRI)

To get Topographic Roughness Index (TRI) of the area under investigation, (**Riley et al. 1999; Migoń & Michniewicz, 2017**) the following equation within the ArcGIS environment is used:

TRI = (Smooth areas - Min R) / (Max R - Min R) **(2)**

It seems that most of the parts of Al-Amghr Valley basin fall within the category of lands with high and mean topographic roughness in most of its parts, which appear in red color with its gradations when compared to the neighboring areas (the basins of the neighboring valleys). But the low parts appear in white, Figure (9) show that the most parts of the Al-Amghr Valley basin fall

within the category of lands with high topographic roughness in most of its parts. The medium parts appear in red and their gradations when compared to the neighboring areas (the basins of the neighboring valleys), shown in white, **Figure (9)**. However, the southwestern parts of the basin (inside Iraq) appear with low roughness - in blue

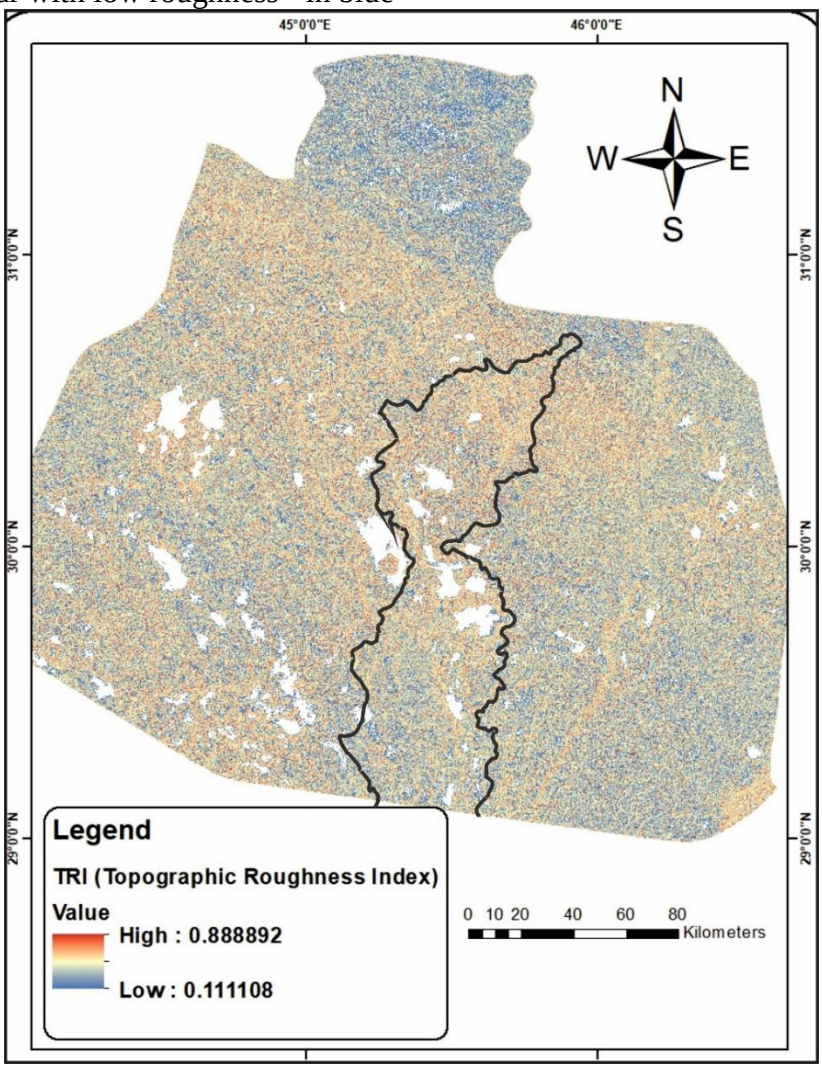

Figure (9) Extracting indicator of Topographic Roughness Index (TRI) for the area

Therefore, parts with high topographical roughness appear while there are low topographical areas suitable for being natural lakes to collect rainwater in case small dams are used in these locations of the Iraqi desert. These locations can contribute to preserve biodiversity in this water-scarce region in light of global climate change and its dangerous repercussions that emerge in these regions recently.

In general, this indicator shows the severity of water erosion that is prevalent in this region during the Pleistocene age.

3.2.3. Results of the spatial analysis by use of remote sensing:

The river valleys channels can be generally identified by GIS (**Pánya, 2021**). Therefore, remote sensing results are based on DEM, and ArcGIS application show that Wadi Al-Amghr represents one of the major valleys in the region, and its stream order is ranked 7 even before it enters Iraqi lands (which confirms the large size of this valley). The results of remote sensitivity also show that the main course of Wadi Al-Amghr (apparently) is similar in behavior to the rest of the valleys of Iraq in the Western and Southern Desert in terms of its general extension towards the north and northeast, and in line with the direction of the slope of the land, as shown in figure (8) and (10).

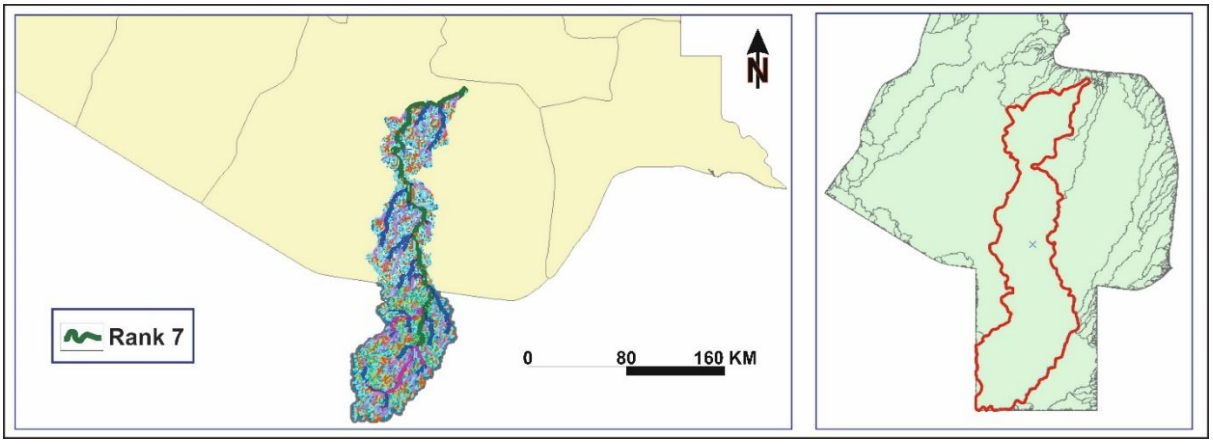

Figure (10) Wadi Al-Amghr basin and the order of its mainstream

Wadi Al-Amghr stream size turns it to behave in similar way like major desert valleys such as Wadi Houran, Shu'aib Abu Talha and Al-Khur … etc., by ending (downstream) its stream into the Euphrates River, but what is real on the ground differs from theoretical conclusions provided by remote sensing processes using ArcGIS. Due to natural reasons that lead to this result, the situation shows mismatch between the ideal course of Al-Amghr Valley and its current course on the surface of the earth.

3.2.4. Field study results:

The field study of the region (Figure 6) shows that Wadi Al-Amghr, which flows from the north-northeast from Saudi lands then it enters Iraq after 10 km and it abnormally divides into two branches. The main branch from flows towards the west and the second branch flow to the east as shown by the field study. This means it is a recent tectonic activation caused the valley to change the direction of its stream and split into two branches

Moreover, all official government maps indicate the dispersion of Wadi Al-Amghr when enters Iraq but it is not connected to the desert valleys located south-west of Busayyah city that located to the north of the area, and flows into the Euphrates River, fig. (10)

3.2.5. Results of remote sensing and comparison with the results of the field study:

Remote sensing data show the direction of Wadi Al-Amghr ideal stream from Saudi Arabia and divide from the stream of Wadi Al-Batin until it reaches its downstream in the swamps located on its right bank of Euphrates (figures 8 & 10). This is an ideal valley stream that appears on the

ground. Therefore, the region digital elevation model (DEM) in the ArcGIS program has shown the history of Wadi Al-Amghr stream quite clearly by highlighting all its previous streams (main and secondary). It represents the ideal stream that was previously shown on the earth surface during the rainy ages (Pleistocene) but its original course is changed by recent tectonic activity.

The field study reveals that the division of Wadi Al-Amghr stream in Iraq is towards the west and the east by 10 km from the border of Saudi Arabia, which confirms the occurrence of a recent tectonic activation that leads to Wadi Al-Amghr river stream and behaves in such abnormality, as shown in Figure (11).

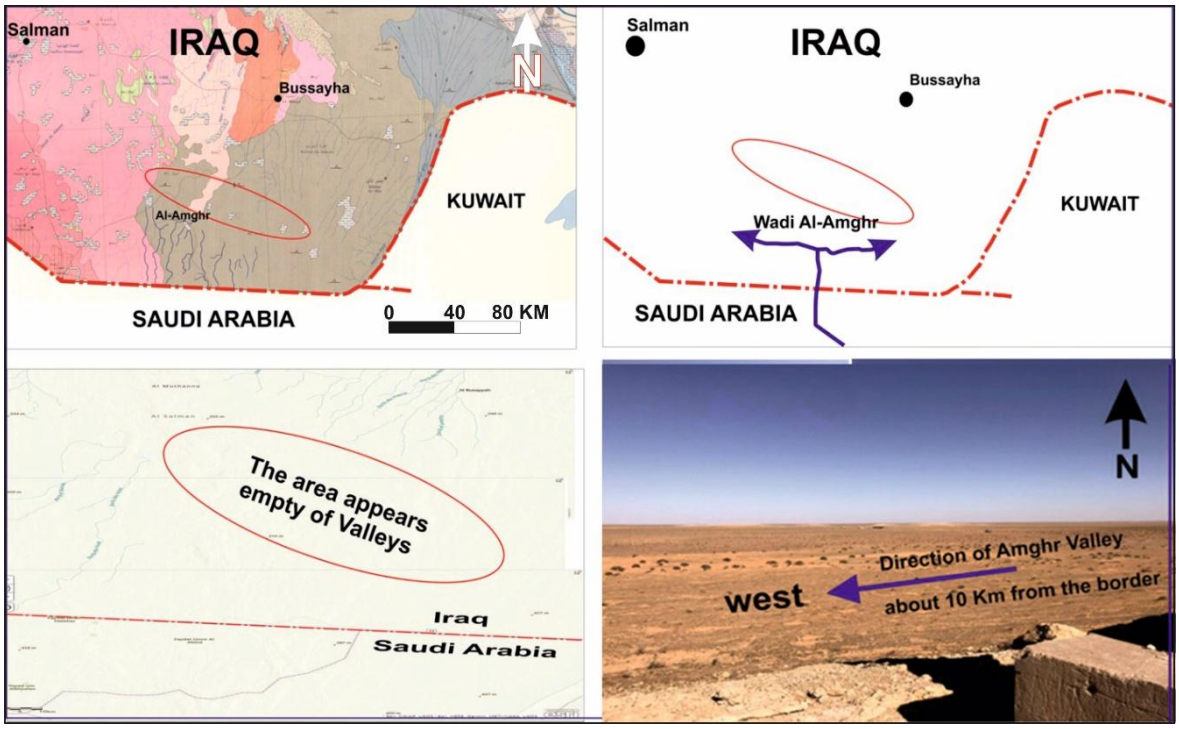

Figure (11) The deviation of the stream of Wadi Al-Amghr from the north to the west and the east after entering the Iraqi lands, due to the recent tectonic activation that occurred in the region

The region seems free of desert valley streams as compared to its neighboring regions in all areas of the Western & Southern Desert of Iraq. This area shows clear anomaly in it, which leads to change the directions of the streams of its valleys. These valleys are running normally from the south to the north according to the general slope and topography of the land there, but not as the case now, where its streams currently follow directions to the east and west in the Al-Amghr region. They do not return to its natural case in the flow-direction from the south to the north only after they cross Al-Amghr region, which is subject to recent ground uplifting operations. This uplifting process impact is directly reflected in the directions of Al-Amghr valley course and its branches until now.

However, this recent tectonic activity with the topography of the region have create low areas similar in their forms to small local basins (Figure) that could be utilized as small lakes after the construction of some small earth dams on the courses of this valley. The dams contribute to

regions' economic development and protect preserve various forms of wildlife. Furthermore, the development of this region will create an eco-tourism area, where the development of ecotourism can achieve environmental, economic, social, cultural, and institutional benefits for this region. Therefore, it is possible to turn this area into ecotourism destination with important national potential for tourism in the twenty-first century (**Al-Gurairy & Al-Omary, 2021**).

Geographic information systems (GIS) play a significant role in the thematic mapping to collect, analyze, visualize store and deliver geospatial data today. Also, the Thematic mapping of the river basins allows for efficient use of natural and water resources in these deserts region (**Chymyrov & Ismailov, 2021**).

3.3. Neotectonics activation and its effect in the direction of Wadi Al-Amghr

The effect of tectonic activation on the surface of different regions of Iraq has been discussed by many researchers and scholars. **Lees and Falcon (1952)** study showed the effects of recent tectonic activation in southern Iraq, which caused continuity of marshes for a long period of time without being filled with silt, and Tigris and Euphrates alluvial deposits. **Mitchle (1957)** presented the impact of recent tectonic movements on the sedimentary plain area, including the rise of the lakeside terraces of Razzazah and Habbaniyah lakes. **Voute (1957)** gave a detailed explanation of the effect of recent tectonic movements on the development of Razzazah Lake and its relationship to the change of Euphrates ancient stream. This represents one of the evidences that confirm the impact of recent tectonic activation on rivers and the change of their streams.

Professor Jafar Al-Sakani recent studies, who is an expert in National Oil Company, is interested in the topic of linking recent surface river network systems with the development of subsurface geological structures and their relationship to the probabilities of oil traps. **(Al-Sakani 1975 and 1993) Al-Qaiem (2011)** study shows the geomorphological evidence of recent tectonic activation in Al-Jazira desert area of Iraq.

Regarding the study area (Al-Amghr area), the observations indicate that the recent tectonics result in ground uplifting during the early and beginning of the middle of the Pleistocene. It is the area that currently appears devoid of main valley streams, and it is a buffer zone between the course of Wadi Al-Amghr in the south and the valleys that are located to the north, specifically west of Busayyah (Wadi Abu Ghar, Abu Ghuwair, Al-Kusayr, Al-Ash'ali ... etc.), as previously shown in Figure (10, 11).

Similarly, the uplift and subsidence movements impose reorganizations of the hydrographic network of the catchments with the alternation of the erosion and sedimentation processes that create certain fluvial style pattern. (**Grecu et al., 2021**).

It should be noted that the tectonic nature of the region (Figure 3A) has a positive effect on the possibility of tectonic uplift movement in this this part, and it is similar to the tectonics of the extended region between Al- Shannafia and Al-Samawa (located at the Euphrates –northwest of the study area). This region shows tectonic uplift t leads to rejuvenation phenomenon of Euphrates in the early twentieth century. (**Al-Ghurairy 2019, Al-Ghurairy, et al., 2018, Al-Jobury & Al-Ghurairy 2017**). The main influence on the formation of non-anticlinal folds traps is exerted by the tectonic (including geodynamic) factor, sedimentation lithofacies conditions, secondary processes, geochemical, and geofluid-dynamic conditions. (**Schuster & Punanova, 2021**).

Furthermore, the valleys located in the north of Al-Amghr region, like Wadi Al-Asha'ali and possibly Wadi Al-Kusayr represent the original northern part of Al-Amghr valley. But they separated from it due to tectonic activation as a result of a comparison of the ideal basin shape of Wadi Al-Amghr in its northern part (Figure 10) and the degree of congruence with the shape and current position of Wadi Al-Asha'ali basin. All of these desert valleys (Al-Asha'ali and Al-Kusayr) are located in the north of Al-Amghr region).

Morphometric and hydro-geomorphological analysis reveals a total of Al-Amghr river watershed entered into Iraqi territory in one main river stream but probably subdivided into two branches as a reason by Neotectonic activation, but not by capturing another stream.

4. Investigation of hydrocarbons

There is a direct relationship between hydrocarbon content and the intensity of Neotectonic movements in the world. However, their impact is usually accompanied by a deterioration of the shielding properties of the covers within the intensely growing structures and the penetration of hydrocarbons into the upper horizons of the cover.

In this case, the destruction of the upper deposits of multilayer fields and the formation of near-surface hydrocarbon anomalies can occur. More details can be found in the book entitled "Fundamentals of the theory of geochemical fields of hydrocarbon accumulations" (**Petukhov and Starobinets, 1993**). The seismic activity of the territory contributes to the formation of temporary hydrocarbon and groundwater filtration paths from the underlying deposits. As a result of the ground uplifting operations, hydrocarbons infiltrate into these places (place of anticline fold) that were subjected to ground uplifting, which formed an anticline fold.

It can be assumed that the rise of the Arabian plate is generally favorable for the accumulation of industrial hydrocarbon deposits. According to (**Markovsky, 1973; Bakirov, 1982**) study, they agree with the principle that recent tectonic activation works to uplift one area and push down another, which forms anticline folds and acts as a trap for hydrocarbons. This will rush towards the top of the anticline fold due to the effect of the intense pressure from the descending earth layers that pushes the hydrocarbons to the top of anticline fold. The heterogeneity within the Arabian plate, according to (**Al-Gurairy, 2019**), makes it possible to identify promising areas of hydrocarbon raw materials within large zonally grouped blocks including Al-Amghr area.

The latest facts provide additional information in favor of prospecting hydrocarbons in this area depending on the recent tectonic activation. The region was previously detected for hydrocarbons as in other similar areas of the Southern Desert located southwest of Al-Najaf Al-Ashraf that was affected by recent tectonic activation. It is worthy to note that Al-Najaf located in the north of Al-Amghr area. (**Al-Gurairy, 2019**).

Figure (12) shows that the area, on one hand, is expected to be major trap for hydrocarbons since it is affected by the movements of recent tectonic uplift because of the course of the Al-Amghr Valley, and its separation from its northern parts, which have turned into independent valleys now. On the other hand, it is because the source rocks of these hydrocarbons that present within Cretaceous sedimentary strata and produce the same sedimentary rock strata for oil and gas in Iraq, Saudi Arabia, and even Kuwait. So, it is expected to find large oil trap in the Al-Amghr region as a

result of the recent tectonic activation (**Al-Gurairy, 2019; Al-Gurairy, et al., 2018; Alatabi, 2014).**

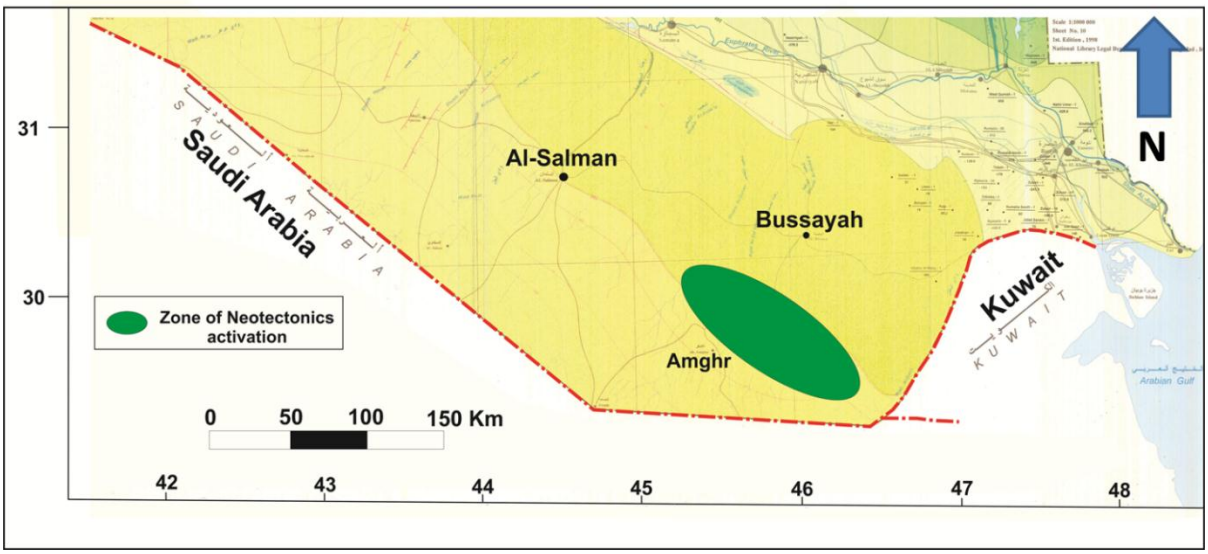

Figure (12) the area that is expected to be a major trap for hydrocarbons and groundwater based on the availability of source rock and occurrence of Neotectonic activation processes (Neotectonic map of Iraq, after Deikran and Sissakian, 2008)

Based on the aforementioned information, oil and gas are very likely to gather at the top of the anticline fold, which resulted from recent tectonic movements in the Al-Amghr area. Such kind of exploration has great economic and developmental importance in this desert area, which will give the region more attention and care than before. More than 62% of the groundwater samples are unfit for consumption as drinking water (**Al-Mutawqi et al., 2021**).

5. Conclusions:

The current study presents a clear approach depending on geological - geomorphological sets, remote sensing data, and the use of geographic information systems applications along with a detailed field study.

The work aimed to understand the geological framework of the area and the conditions that lead to the change of Wadi Al-Amghr course to its direction from north to west, east and the appearance of an area devoid of the main streams of valleys between Al-Amghr area and southwest of Busayyah.

The study of Wadi Al-Amghr and its hydrological basin represents an important example of the topography and geomorphology that is structurally controlled, where recent tectonic activation plays the main effect on the occurrence of the process of changing the course of Wadi Al-Amghr and the separation of the northern part of its basin to appear as an apparently independent valley. This particular morphology is probably guided and accelerated by a Morpho-structural context represented by the active recent tectonic activity the region has experienced during the Quaternary. So, the remnants of the hydrographic network are also influenced here by tectonics and lithology.

The researcher agrees with the researchers' views (**Markovsky** and **Bakirov**) that applied to other areas in Iraqi desert in our previous studies, where commercial quantities of oil and gas in those regions are subject to recent tectonic activation. So, it is expected that Al-Amghr area contains large quantities of various resources (oil and gas). The exploitation of these natural resources will contribute to the development of this area and raises the quality of life of its residents. The integration of remote sensing data with geographic information systems, and field studies provides a cost-effective method for detecting and investigating the presence of many resources and groundwater in desert areas. It is also worth noting that the possibility of the growth of subsurface salt domes has a major role in influencing the faults system in the region and causing tectonic activation. This tectonic activation process may not result in the detection of hydrocarbons in the region if the cause of the activation os the growth of salt domes in the ground. The economic value of such studies lies in the possibility of providing a new source of fresh water for the population who really depend on groundwater for their needs. The process can be achieved by exploiting the flow of water in the streams and valleys of the region during wintertime and find appropriate means to store it. The study also proposes the establishment of a natural reserve based on a geological - geomorphological basis in Al-Amghr area to highlight the processes of recent tectonic activation in the region and to contribute to the region's economic development.

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