Study of hydrocarbon potential in the Western Desert (Northwest of Anbar)

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Abstract

The study area is located in the western part of Iraq within the administrative borders of Anbar Governorate and adjacent to the Iraqi-Jordanian-Syrian borders within the 37 zone and an area of 61600 km². The region is characterized by its rugged desert nature, where altitudes range between (500-900) meters above sea level, interspersed with some valleys, and the altitudes increase towards the southwest. Structurally, the study area is located in the stable shelf within the Al-Ma'aniyah-Al-Rutba zone (Al-Rutba belt) and the Al-Salman-Hatra zone (Akashat-Kubisa belt) .
The study aim to determine the hydrocarbon presence in the Western desert region using remote sensing technology and to indicate the type of trap, whether it was a structurally, stratigraphic or combined.
The map of the Bougier anomalies showed the values of gravity ranging between (-60 and -10) mg Gal within the study area, increasing towards the north and north-east and decreasing towards the south and southwest, and that the axes of the anomalies within the region are towards northwest - southeast. These anomalies reflect the effect of the movement of the base rocks on the crustal rocks. The residual gravity showed the presence of a number of positive anomalies within the first study area, whose value is (4) mg Gal in the eastern part of the study, whose value is (6) mg Gal, and the second, whose value is (4) mg Gal, in the northern part, in addition to two anomalies whose value is (8) mg Gal located in the western part of the study. Along the Iraqi-Jordanian border. The magnetic intensity map showed the presence of two magnetic anomalies with high values, the first located in the southeast of the region and the other in the northwest of the region, that these two anomalies reflect the presence of two convex high in the region. On the other hand, two negative anomalies appear in the center and north of the region that reflect the presence of a concave depression in that part of the study area.

1-1 Geographical location

The study area is located in the western part of Iraq within the administrative borders of Anbar Governorate and adjacent to the Iraqi-Jordanian-Syrian borders with an area of (61600) km2. The area is characterized by its rugged desert nature, Figure (1-1). The study area was identified by the coordinates below according to the (UTM WGS 84) system within the range (37), Table (1-1).

Table 1-1 Coordinates of the study area

Symbols	Easting	Northing
A	611789	3768382
B	741299	3748219
C	713248	3626867
D	510365	3615356
E	483068	3694066

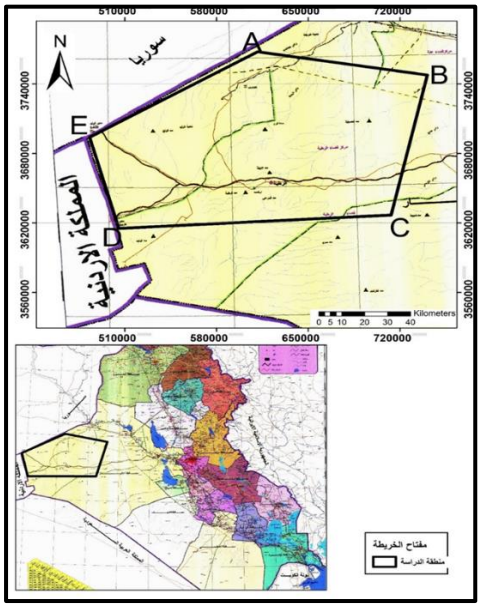
1-2 Objective of the study

The study aims to determine the possibility of hydrocarbon presence within the study area, showing the initial indicators to indicate the type of trap, whether structural or stratigraphic

1-3 General description of the structures present in the area

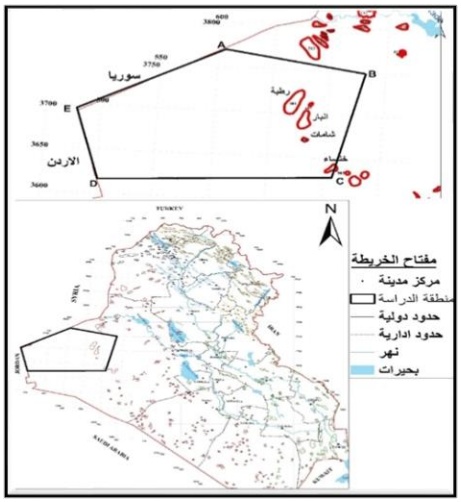
According to the hydrocarbon potential map issued by the Oil Exploration Company in 1989, the study area contains a number of structural domes, Figure (1-2). The following is a description of the structures present in the area:

1- Anbar structure 2- Rutba structure 3- Shamat structure



شكل ١- ١ الخريطة الادارية للعراق توضح حدود منطقة الدراسة

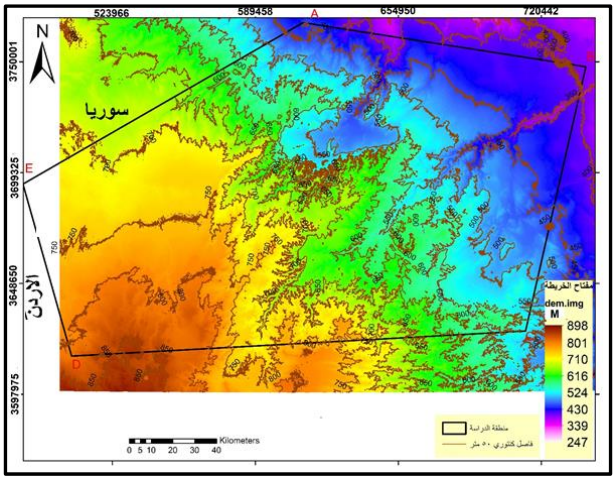
المصدر: الهيئة العامة للمساحة، ٢٠١٠



شكل ١- 1 خريطة العراق مثبت عليها الدوال التركيبية ضمن منطقة الدراسة
المصدر: خريطة الاحتمالات الهيدروكربونية ١٩٨٩

٤-١ Topography of the region

The region is a rugged desert with elevations ranging between (247-900) meters above sea level and increasing towards the southwest, interspersed with a network of water drainage channels during the rainy season that extend from the high areas to the low areas covered with sandstone and gravel. There are many depressions in the region such as the Al-Kaara Depression in addition to valleys formed by erosion factors such as Akashat, Al-Rataka, Aamj, Hawran, Figure.(١-٣)



شكل ١- ٣ خريطة١-٥Surface Geology

The study area reveals various formations dating back to different geological eras that reflect the influence of multiple structural forces that affected them, Figure (6-1) as follows

1- The Tertiary Period:

-Miocene formations represented by the Euphrates Formation in the far north of the patch.

-Eocene formations represented by the Dammam Formation in the far west of the patch.

2- Cretaceous formations represented by the Dakmah, Tayyarat-Hartha, Rutbah, Mas'ad, Mawdud and Nahr Omar formations in the middle of the lower patch.

3- Jurassic formations represented by the Najmah, Muhayyur, Amj, Husayniyat and Ubaid formations in the middle of the upper patch.

٤-Triassic formations represented by the Zur Hawran and Maloussa formations in the middle of the upper patch

5- Permian formations represented by the Ka'ra Formation within the Ka'ra Depression area in the middle of the upper patch الارتفاعات . الطوبوغرافية لمنطقة الدراسة باستخدام برنامج - DEM

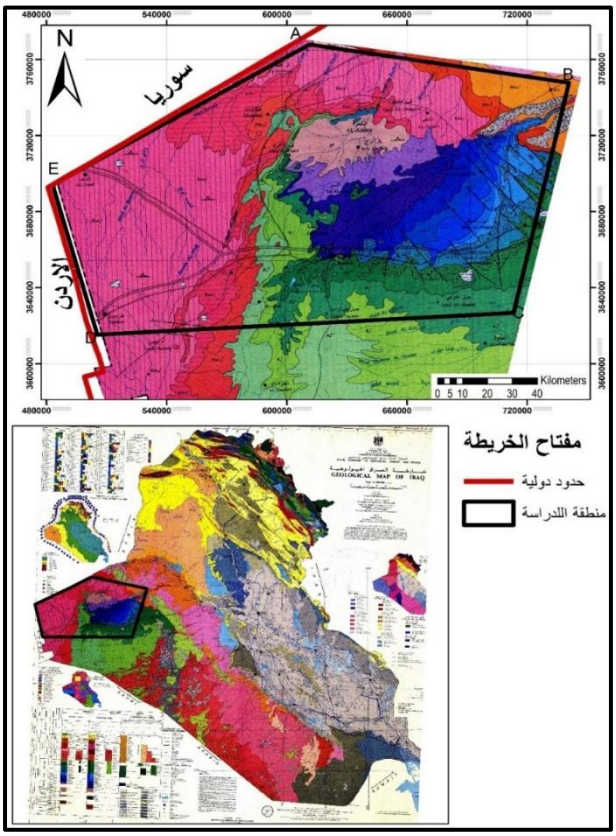


Figure 1-6 Surface geology map of the study area
Source: Iraqi Geological Survey, 2012

1-6 Subsurface geology

The information from the Akkas-1 well was relied upon to identify the subsurface geology and describe the stratigraphic sequence in the study area, Figure.(٧-١)

١-٦-١ Tertiary formations

-Euphrates Limestone Formation (Early Miocene) The formation consists of porous limestone rich in bottom fossils with the presence of dolomite rocks and flint sometimes and the presence of sandstone, which is exposed on the surface.

- Kirkuk Group (Oleocene) The formation consists of limestone rocks with dolomite rocks.
- Dammam / Jadala Formation (Eocene) The formation consists of limestone with dolomite rocks and sandstone rocks in some parts of the formation.
- Al-Aliji Formation / Umm Radmah (Paleocene - Early Eocene) consists of shale with thin bands of mudstone limestone and dolomite rocks interbedded.

1-6-2 Cretaceous Formation

Tayarat Formation (Late Campanian - Maastrichtian) consists of mudstone limestone rocks interbedded with sandstone rocks in addition to the presence of a layer of fine-crystalline dolomitic limestone.

1-6-3 Paleozoic formations

- The red layers consist of shale and red clays, and due to the absence of animal and plant microfossils in the section, it was not possible to determine the age of the formation.
- Al-Ka'ra Formation (Late Carboniferous-Early Permian) The formation consists of clastic sediments composed of sandstone and shale with the presence of clay and mudstones.
- Al-Harror Formation (Late Devonian-Early Carboniferous) consists of calcareous dolomatite rocks containing shale and the presence of shale in some parts.
- Aura Formation (Late Devonian-Early Carboniferous) The formation is characterized by the dominance of shale rocks with successive layers of silty sandstone.
- Kista Formation (Late Devonian-Early Carboniferous) consists of sandstone rocks and alternates with silty shale rocks in some parts.
- The Berspeke Formation (Late Devonian) consists of clastic sediments with mudstone.

- The Akkas Formation (Silurian) The Akkas Formation is divided into two main members:
- The Qaim Member: consists of a succession of shale with silt and some fine sand with a thickness of 745 meters, the shale varies in color from gray to dark gray green (Geological study of the Akkas field, 1994).
- The Hoseiba Member: consists of black laminated shale compacted with bituminous containing pyrite crystals with a high percentage of organic carbon, this member is characterized by the presence of two layers of black hot shale, the upper layer with a thickness of (20) meters and the lower layer with a thickness of (40) meters.
- The Khabur Formation (Ordovician) The largest part of this formation with a thickness of (1910) meters was penetrated in the Akkas-1 well. The formation is divided into the following parts:

1. Upper Sand Member: Its thickness ranges from (21-40) meters, and consists of a succession of sandstone with silt and shale.
2. Upper Shale Member: The formation consists of dark lead to black compact shale, and contains silt interbedded with alluvial sand bands.
3. Lower Sand Member: This member consists of sand interbedded with silt and clays.
4. Lower Shale Member: It consists of dark shale, and was penetrated in the Akkas-1 well only.

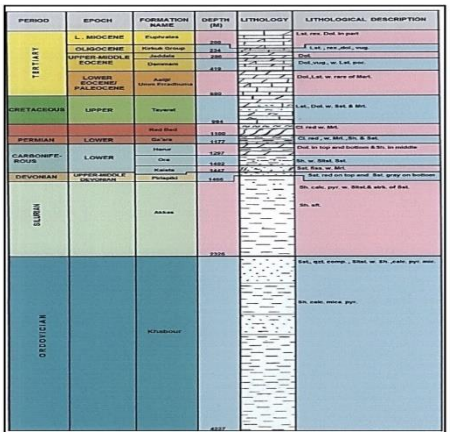


Figure 1-7 Stratigraphic sequence of the well Akkas-1
Source: Geological and Production Information Book, 2016

1-7 Structure of the area

The structural map of Iraq showed that the study area is located in the stable platform within the Ma'ani-Rutba belt (Rutba belt) and Salman-Hadr (Akashat-Kabisa belt), Figure (1-8), (Al-Kazemi et al., 1996).

Ditmar, 1979, stated that the Western Desert, including the study area, is closely linked to the structure of the Arabian plate, which represents part of the northeastern slope of the African-Arab platform, as the plate was directly affected by the structure of the crystalline basement rocks dating back to the Precambrian era, and that the cracking in the crystalline basement rocks resulted from the movements of the Hijaz and Najd, whose impact extended to the continental shelf of the Arabian plate in the form of cracked blocks, and that the nature of the structures and the pattern of the spread of the structural axes in The Western Desert region in general is a reflection of the effects of the basement rocks of the Arabian Plate. (Jassim & Goff, 2006) indicated that the longitudinal and transverse fault systems do not differ in their intensity and nature of their distribution throughout the Arabian Plate and Iraq, and that these faults are what formed the structural fabric and structural phenomena in the stable platform. Two longitudinal faults pass through the region, namely the Tar Al-jil Fault and the Euphrates boundary Fault, which extend in a northwest-southeast direction, in addition to the transverse Anah-Qalat Dizh Fault, which extends northeast-southwest, Figure (1-9).

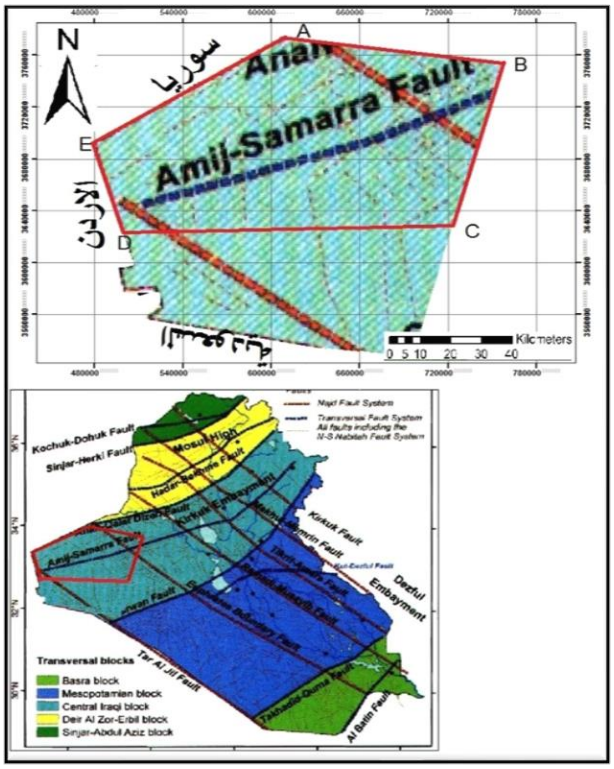


Figure 1-9 The structural divisions map of Iraq shows the longitudinal and transverse fault systems affecting Iraq and the study area Source: Jassim & Goff, 2006

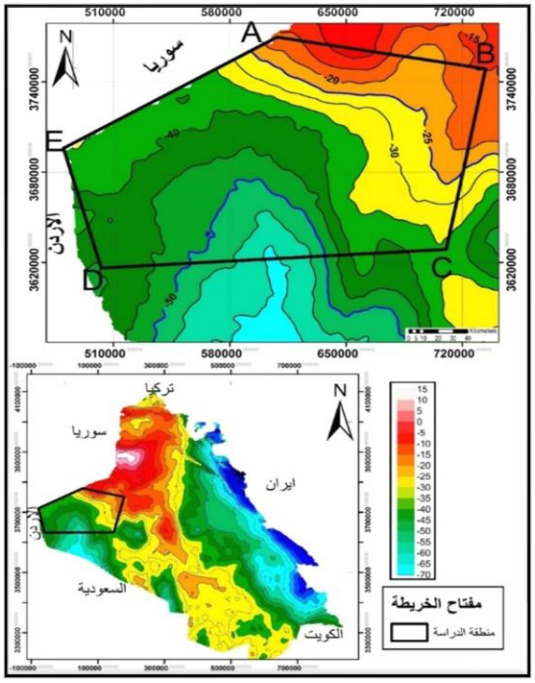
1-8 Previous geophysical surveys

١-٨-١ Gravity surveys

The registration of gravity points in Iraq was carried out in the 1940s by foreign companies working for the Iraq Petroleum Company with a mesh density of (5) km2 for the measurement points, and gravity maps were drawn after making field corrections. In 2010, the British company GETECH Group made the corrections and converted the maps from old paper formats to digital formats and drew gravity maps with high clarity. The Bouger anomaly map, Figure (1-10), showed that the gravity values range between (-60 and -10) millicals within the study area, increasing towards the north and northeast and decreasing towards the south and southwest, and that the axes of the anomalies within the area are towards the northwest-southeast. These anomalies reflect the influence of the region on the forces and ground movements resulting from the movement of basement rocks in the rocks of the Earth's crust and the increase in the thickness of the crustal layers towards the north and northeast and decrease towards the south and southwest.

1-8-2 Gravity Residual

The gravity residual map is derived from the Bouguer map after removing the gravity values that reflect the influence of basement rocks. The map showed the presence of a number of positive anomalies within the study area, the first with a value of (4+) millical in the southern part of the area and the second with a value of (8+) millical in the northern part, in addition to two anomalies with a value of (4+) millical located in the western part of the study along the Iraqi-Jordanian border. These anomalies reflect the presence of convex structures within the region. The map also showed the presence of a negative anomaly with a value of (8-) millical reflecting the presence of a structural depression in the middle of the region, Figure (١١-١).



شكل ١ - 2 خريطة شواذ بوجير موضحا عليها منطقة الدراسة

المصدر: GETECH, 2010

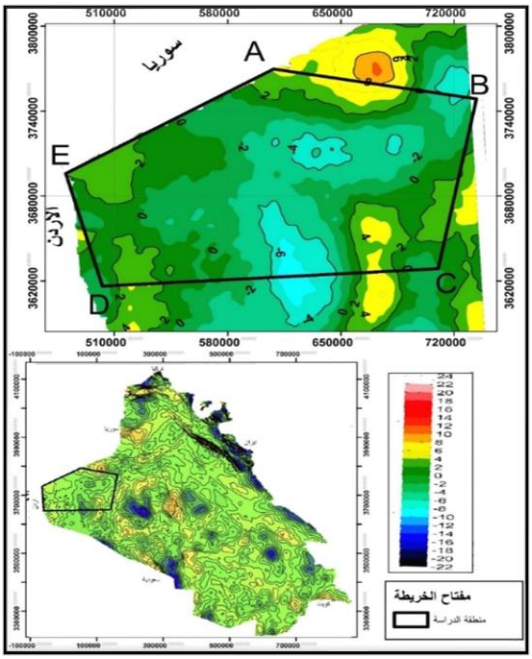


Figure 1-11 Gravity Residual Map
Source: GETECH, 2010

1-8-3 Airborne Magnetic Survey

The airborne magnetic survey was carried out in Iraq in 1974 by the French company (CGG) for the Geological Survey and Mining Authority at a uniform height of (140) meters above the topographic surface and with distances of (2) km between the airborne survey lines. In 2010, the British company GETECH Group made corrections and converted the maps from paper format to digital format and drew magnetic maps with high clarity, in addition to converting the total magnetic intensity map to the vertical component corrected from the effect of the Earth's pole, which shows the correct location of the structure or phenomenon. The magnetic intensity map represents a reflection of the depth and geochemical nature of the crystalline basement rocks that affect the recording devices more than the sedimentary cover rocks (GETECH, 2010).

The map showed that the magnetic intensity values ranged between (4800-5080) Tesla, where the magnetic intensity values increased in the northwestern and southeastern parts and decreased in the center of the study area. The map showed the presence of two anomalies with high magnetic values, the first located in the southeast of the area and the other in the northwest of the area. These two anomalies reflect the presence of two convex highs in the area. On the other hand, two anomalies with low magnetic values appear in the center and north of the area, reflecting the presence of a concave depression in that part of the study area, Figure (1-12).

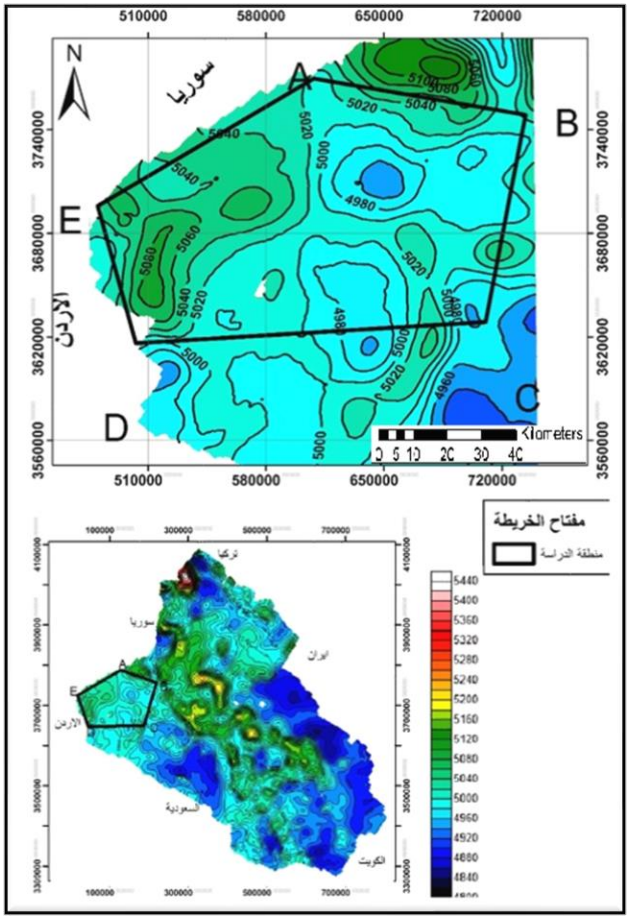


Figure 1-12 Magnetic intensity map corrected to the vertical component
Source: GETECH, 2010

2-1 Hydrocarbon potential and petroleum system in the Western Desert region

Exploration results in Iraq and neighboring Arab countries showed a high probability of hydrocarbon accumulations in the deposits of the ancient era because they contain generative rocks containing a good amount of organic materials in more than one formation and with good petroleum efficiency in addition to geochemical indicators that indicate the thermal maturity of organic materials in these

deposits in addition to the presence of an integrated petroleum system represented by generative rocks, reservoir rocks and cover rocks (Exploration geological study of the Fadwa-Umm Rashif patch, western Iraq, 2016). The period of marine tyranny at the end of the Ordovician era resulted in the deposition of two units of black shale rich in organic materials. The hot shale layer, rich in organic matter, is considered the main generating rocks, represented by the lower part of the Akkas Formation, with a thickness of (64) meters in the well (Akkas-1), which consists of two units separated by a sealed shale layer, where the organic content (TOC) values range between (0.67-16.67)%, and in the well (Khulaisiya-1) with a thickness of (50) meters and (TOC) values reach (9.95%). The marine origin of these rocks increases their effectiveness in generating hydrocarbons, while within the Devonian sequence, the organic matter content (TOC) rates in the well Akkas-1 reach (1.84%) and the well Khulaisiya (3.45%), and the material that forms it is of continental origin, which may be gas-generating if it is found within the thermal maturity zones. These rocks are spread in the northern parts of the Western Desert region. In terms of reservoir, the high hydrocarbon potential in the Khabur Formation (Ordovician) is found in:

A (34) meter thick area in the upper sandy part, which is characterized by a fracture system with a porosity of up to (7%) and a permeability of (14) milli Darcy, which contains gas and condensates (API=50), and the upper part of the Akkas Formation is represented by the Qaim member, which consists of clastic rocks with a porosity of up to (6%) and a permeability of about (20%) milli Darcy, which appeared to contain oil with (API=42), (AL-Mashaekhy, 2015) The important cover rocks in the Paleozoic section are the shale rocks resulting from the marine tyranny that occurred in the Lower Silurian era, under which the gaseous reservoir rocks are found in the Akkas and Risha fields, in addition to the shale rocks intermingled with the layers of the Ordovician, Silurian and Carboniferous eras, (AL-Mashaekhy, 2015) The presence of all the components of the integrated petroleum system represented by the generative rocks found within the formation The Akkas al-Salori represented by the (Hot Shale) layer, as well as the equivalent of the Mudawwara Formation in Jordan, which is found in the stratigraphic section of the Ordovician Khabur Formation, in addition to the presence of storage factors in the clastic reservoirs of the Akkas and Khabur Formations, as well as the availability of (Shale) rocks within the above section (above and below the presence of hydrocarbons) and their non-leaching as they are ideal cover rocks, in addition to the faults resulting from the movement of the basement rocks, as well as the effective ground movements such as the Hercynian and Caledonian movements, which contributed to the formation of many faults within the stratigraphic section, and this helped in the migration of hydrocarbons (AL-Mashaekhy, 2015).

2-3 Expected possibilities of reservoir rocks

The main reservoir rocks of the Paleozoic era in the western desert region of Iraq are equivalent in terms of their facies and age to those rocks found in both Saudi Arabia and the Jordanian Risha field, and are represented by sandstone rocks belonging to the Ordovician age (Khabur Formation) and the Silurian age (Akkas Formation) and are located within the depth of (3100-3200) meters in the Akkas-1 well, where the interim and completion tests of the well (Akk-1) showed the presence of important hydrocarbon accumulations within the layers of the stratified sandstone belonging to the Akkas Formation, which are successive with the shale layers. The results of the tests of the Akkas-1 well showed the presence of high values of the API degree of (42) within the Silurian Akkas Formation, as well as the presence of gas accumulations within the upper limestone belonging to the Ordovician Khabur Formation, (Al-Haba, 1994). Based on (Al-Haba, 1994), Thermal maturity and burial history of the hot, radioactive shale layers (Silurian) in the (Akkas-1) well show that the migration of hydrocarbons began in the Lower Triassic period and that the direction of

migration in Saudi Arabia and Iraq is towards the west, Figure (2-1).

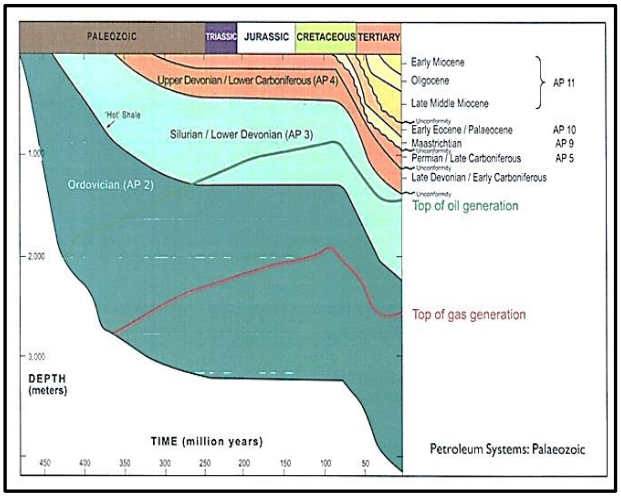
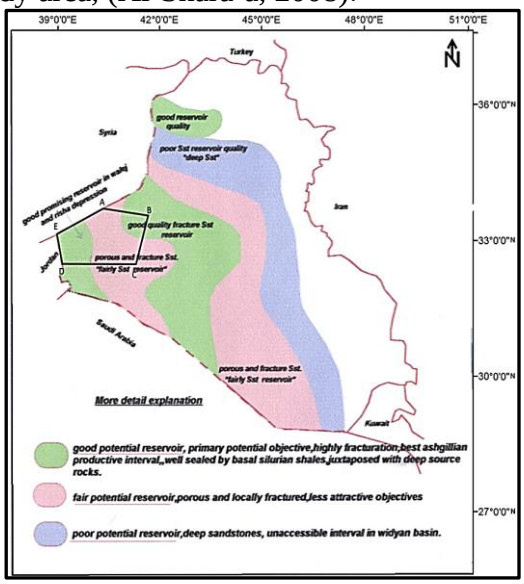


Figure 2-1 Diagram showing the history of burial and thermal maturation in the Akkas-1 well
Source: Cole et al., 1994

2-3-1 Hydrocarbon potential of the Ordovician succession

The Upper Ordovician sandstone deposits were deposited in a complex deltaic environment where the Ordovician Khabur Formation is characterized by low porosity in the Akkas-1 well, and the sandstone reservoirs are fractured in the upper part and have a total thickness of (35) meters containing pure gas (API 50). The Ordovician Khabur Formation was penetrated in the Akkas and Khulaisiya fields and was produced within the section in the Akkas-1 well and wells drilled east of Jordan within the porous sandstone layers, and the Upper Ordovician succession represents the best reservoir which lies directly below the hot, radioactive shale layers of the Silurian age. The best Ordovician cumulus facies are in the deep sandy intervals of the Upper Ordovician (Ashgillain) associated with porous sandstones and covered by hot Silurian shales. The Khabur Formation is one of the main reservoir targets of the Paleozoic and appears in the stratigraphic sequence below the Akkas source rocks (AL-Hadidy, 2007). Based on the analysis of the core above the Khabur in the Akkas-1 well, the porosity is about (7.6%), the permeability is (0.13 MD) and the density is (2.69 gm/cc). The gas evidences in the upper part of the Khabur Formation within the Akkas and Khulaisiya wells in depths of more than (3300) meters show that the gas evidences migrated from the sandstone layers below the compacted Burj Formation through the fractures present in it. Figure (2-2) shows the hydrocarbon potential map for the Ordovician eras, indicating the study area, (Al-Shara´a, 2008).



شكل ٢ - 1 خريطة الاحتمالات الهيدروكربونية لعصر الاوردوفيشي موضح عليها منطقة الدراسة
المصدر: Al-Shara´a, 2008

٢-٣-٢ Hydrocarbon potential of the Silurian sequence

The Silurian layers were discovered near the Walej depression and the Jordanian border with thickness values exceeding (2100) meters and (1600) meters in the southwest of those areas, and the thickness values decrease as we move east and north. The Silurian sequence consists of successive layers between shale, siltstone and fine-grained sandstone, and the black shale is rich in organic matter below this sequence. The components of the Silurian sequence are important in a distinctive appearance because this system of the sequence behaves as a coarse-grained sedimentary cycle towards the top and is limited by shallow fine to coarse-grained deposits of limestone transformed into red continental sands (Al-Shara´a, 2008). The sandstone rocks in the upper part of the Silurian sequence represent promising reservoirs and

the specifications of the sandstone range from good to poor while the permeability values are average, so the reservoir potential is considered acceptable to good although the sandstone rocks are covered by Silurian and Devonian shale rocks. The important sandstone reservoirs have produced economic quantities of gas in the Akkas field and are located in the Rutba highlands and near the border with Syria. The Silurian sequence reservoirs consist of alluvial shale rocks rich in organic materials in the upper Silurian, where the Silurian formation contains a thinly bedded shallow marine formation and evidence of oil accumulations at a degree of (42 API). As for the gas evidence, it was indicated within different depth intervals in the Silurian section at depths of (1650-1680) meters, (1730-1760) meters, (2000-2050) meters, Figure.(٢-٣)

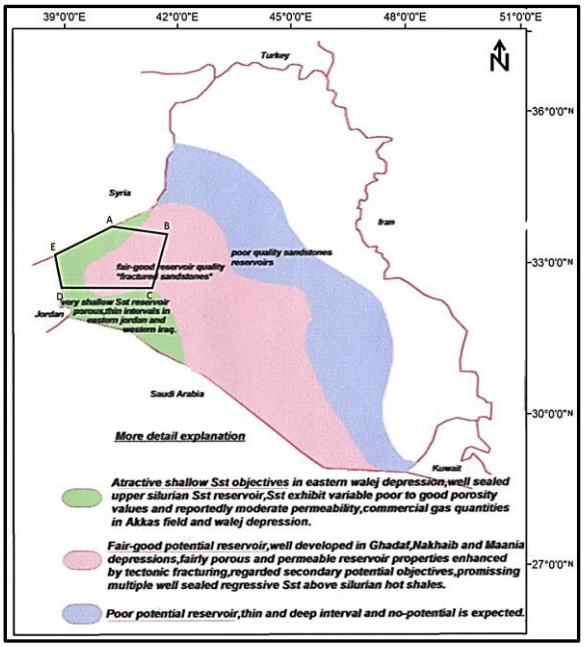


Figure 2-3 Hydrocarbon potential map of the Silurian period showing the study area
Source: Al-Shara'a, 2008

2-3-3 Hydrocarbon potential of the Devonian succession

The Devonian succession is represented by the Harur Formation deposits located in the upper part of the sedimentary system, while the Ora Shale, Kista and Perspecki formations were found in the lower part of the succession. The Devonian sedimentary succession consists of shallow marine clastic deposits and a layer of limestone rocks with shales which are considered as an indicator of deep sedation of the marine retreat phase in the Ma'aniah Depression, Salman High and Rutbah. The upper part of the sequence consists of reefal organic build up carbonate with bioclastic facies, (Al-Shara´a, 2008). The sandstone units of the shallow marine Kista Formation represent good reservoir facies and both Harur and Aura Formations also have good reservoir facies within the Rutbah-Hail Uplift. In some areas, the sandstone rocks containing clayey mudstone components are considered to have poor to acceptable reservoir specifications as found in some parts of the Devonian sequence within the Khulaisiyah-1 well. Figure (4-2) shows the hydrocarbon potential map of the Devonian eras, indicating the study area, (Al-Shara´a, 2008).

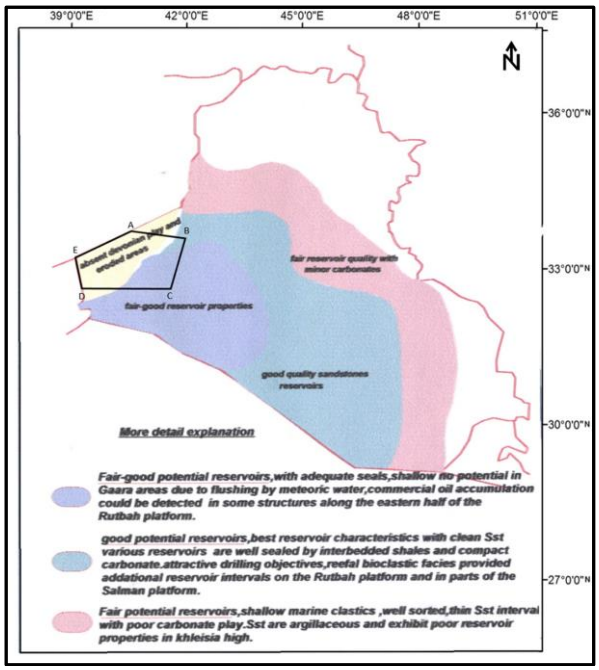


Figure 2-4 Hydrocarbon potential map of the Devonian era showing the study area
Source: Al-Shara'a, 2008

2-3-4 Hydrocarbon potential of the Carboniferous sequence

The facies of the Carboniferous reservoirs are considered to be of a wider extent than the Akkas Silurian Formation and the Devonian sequence. The microfacies of these formations

consist of clayey sandstone and limestone facies. The Harur Formation consists mainly of coralline algal facies and reef and post-reef bioclastic facies deposited in edges on the edges of the platform or the sea shelf and play a role as barrier facies for that platform. As for the Aura Shale Formation, it consists of thinly bedded fluvial and marine clasts and coarse sands expected to be found west of the Rutba High and the areas adjacent to it (Exploration geological study of the Fadwa-Umm Rashif patch, western Iraq, 2016). Carboniferous facies behave as acceptable reservoirs in the southern and western parts of the Iraqi desert. The succession of fractured limestone facies and sandstone facies of the areas adjacent to the Khalisiya and Ana highlands indicate poor to acceptable reservoir characteristics within the study area. Near the Iraqi-Syrian border, the deep intervals of limestone rocks are thick and have secondary porosity resulting from rapid rainwater penetration through these rocks, which produced reservoirs with good reservoir characteristics, after which their reservoir potential was improved by structural fracture processes of the limestone sandstone facies. The Carboniferous sandstone deposits have developed extensively compared to the limestone deposits, as limestone deposits were found in the eastern and northern parts of the Rutba High, the Khulaisiya High, and the west of the Salman High. On the other hand, sandstone deposits may appear in most of the western regions and have poor reservoir specifications, and partially in the Rutba High, most parts of the Rutba-Hail High, the Khulaisiya High, the Al-Ghadf, Al-Ma'aniyyah, and Al-Nukhayb Depressions, and some areas located in northwestern Iraq, Figure (2-5), (Jawzi, et. al., 2002).

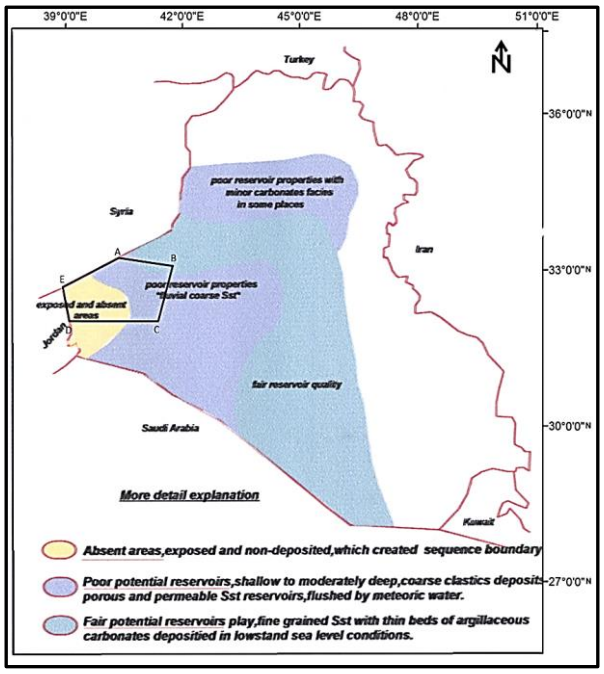


Figure 2-5 Hydrocarbon potential map of the Carboniferous era showing the study area Source: Al-Shara´a, 2008

2-3-5 Hydrocarbon potential of the Permian succession

The shallow marine clastic environment prevails in the lower Permian, while the limestone facies form the upper part of the Permian. Limestone rocks prevail in the northern and eastern parts of Iraq, but the sandstone-clay facies appear in the western regions in the lower part of the Permian, defined by coarse clastics in southern Iraq, equivalent to the pre-Giazerian Formation in Iraq and the pre-Khuff clastic Formation, as well as the Ka'ra Formation in the Rutba Highlands, (Exploration geological study of the Fadwa-Umm Rashif patch, western Iraq, 2016). The Pre-Giazerian clastic formation has developed along the regional trend which was expected to be similar to those formations known in previously explored areas in Saudi Arabia which constitute expected clastic reservoirs in the same pattern, the large fluctuation of the Hercynian unconformity surface prevailing on the exposure surface of the sequences will support the improvement of the reservoir potential, (Exploration geological study of Fadwa-Umm Rashif block, western Iraq, 2016). The Upper Permian represented by

the Giaziri Formation which is distributed in the central and northern regions of Iraq and its thickness decreases in the western regions of Iraq is equivalent to the Khuff Formation Giaziri Formation in southern Iraq and northern Saudi Arabia which consists of clayey mudstone facies and small areas of anhydrite and fine-crystalline dolomite that decreases towards the west and north. The Permian sequences have variable reservoir potential within a range between acceptable to good in northern Iraq and poor within the study area, (Exploration geological study of Fadwa-Umm Rashif block, western Iraq, 2016). The porous zones within the Jiaziri Formation of limestone and dolomite rocks have acceptable specifications and their porosity improves by the process of dolomitization and cracking and forms reservoirs of acceptable quality. On the other hand, the sandstone reservoirs within the Jiaziri Formation have acceptable potential and improve towards the west in the Ka'ra Formation, Figure (2-6), (Jawzi et al., 2002).

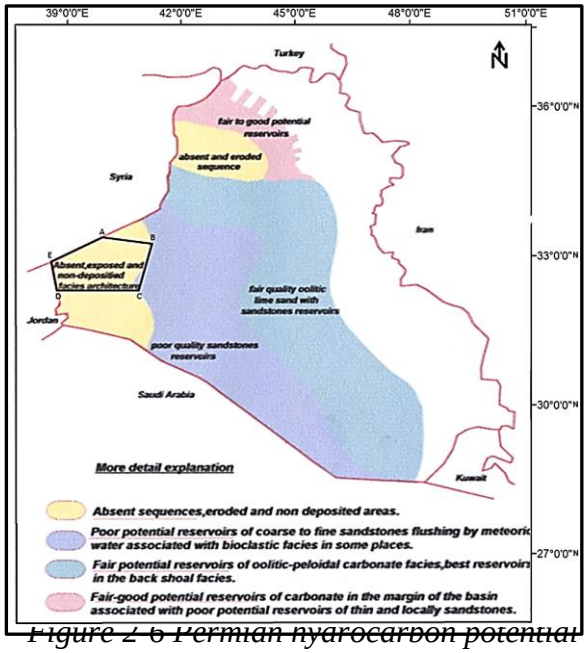


Figure 2-6 Permian hydrocarbon potential map showing the study area
Source: Al-Shara'a, 2008

2-4 Source rocks

The location of the main potential source rocks of the Paleozoic era was determined through geochemical data that included the maturity and richness of rocks in organic matter of the Paleozoic system, which are the hot shale layers of the Lower Silurian era, (Mahmoud et al., 1992). In addition to the rest of the other source rocks, they are represented by shale rocks dating back to the Ordovician, Devonian, Carboniferous and Permian eras. In addition, the probability of source rocks should increase towards the center of the sedimentary basin to the east due to the increase in depth, the prevalence of deep marine conditions and the increase in the thickness of the sedimentary cover. Based on the geochemical analyses of some samples taken from selected areas, the source rocks may play an important role in generating hydrocarbons within the study area.

2-4-1 Generating rocks of the Ordovician era

The Khabur Formation It is highly mature and the total organic carbon (TOC) values range between (0.9-5) % WT in the Khulaisiya-1 well. Good source rocks rich in organic matter have generated a quantity of gas in the northern part of the Rutba plateau, where Ordovician shale rocks with high maturity and high marine organic content were found in both the Akkas-1 and Khulaisiya-1 wells. These rocks are considered good quality source rocks with (TOC) values ranging between (0.9-5) % WT. In another model belonging to the upper part of the Khabur Formation, it has (TOC) values ranging between (0.46-2) % WT in marine conditions and is suitable for generating hydrocarbons. The results of the tests showed that the source rocks in both the Khulaisiya-1 and Akkas-1 wells can generate light hydrocarbons, Figure (2-7), (Al-Haba et al., 1994). 2-4-2 Silurian-Generating Rocks

The hot shale, which is found in the lower part of the Silurian sequence and is widely spread regionally, represents the maximum flooding surface within the thick section, where the thickness of the radioactive shale layers in the western and northwestern regions specifically in the wells (Akkas-1) and (Khalisiya-1) is about (65) meters, and those layers were deposited under reducing environment conditions. In the well (Akkas-1), the (TOC)

values range between (0.6-16.67) % WT under conditions البيئة البحرية وفي بئر (خليصية-١) حوالي (٩,٩٥)%، (دراسة جيولوجية استكشافية لرقعة فضوة-ام راشف غرب العراق، ٢٠١٦).

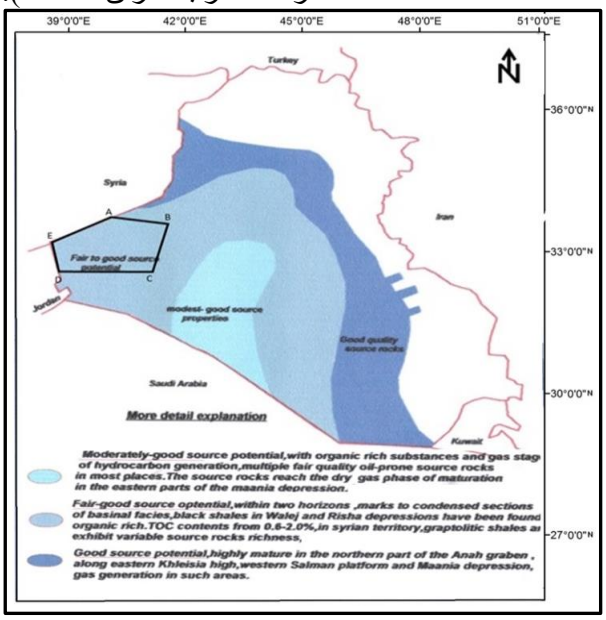


Figure 2-7 Hydrocarbon potential map of the source rocks of the Khabur Formation (Ordovician)
Source: Al-Shara'a, 2008

The availability of all the basic conditions for the rocks generated in these layers makes them the best source rocks for generating liquid hydrocarbons in the Western Desert region, which produced very light oil, condensates and gases containing very small percentages of sulfur, as in the Akkas field, and still have the ability to generate condensates and gases,

Figure.(٢-٨)

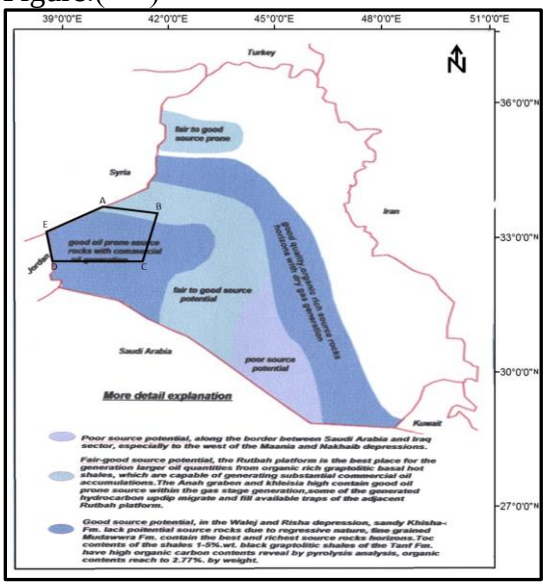


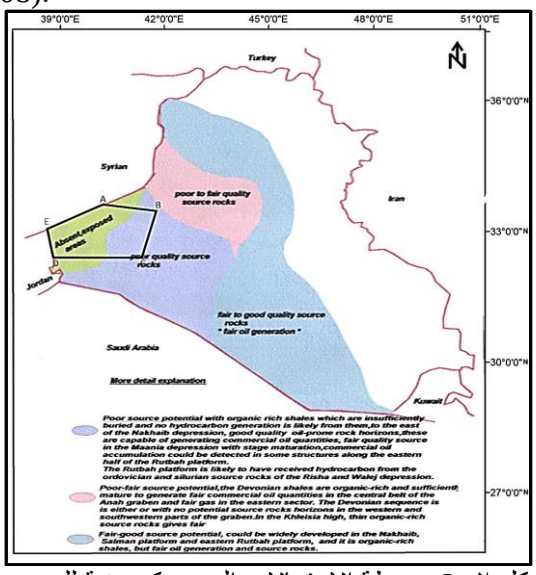
Figure 2-8 Hydrocarbon potential map of the source rocks of the Akkas Formation (Sylurian age)
Source: Al-Shara'a, 2008

2-4-3 Devonian-age rocks

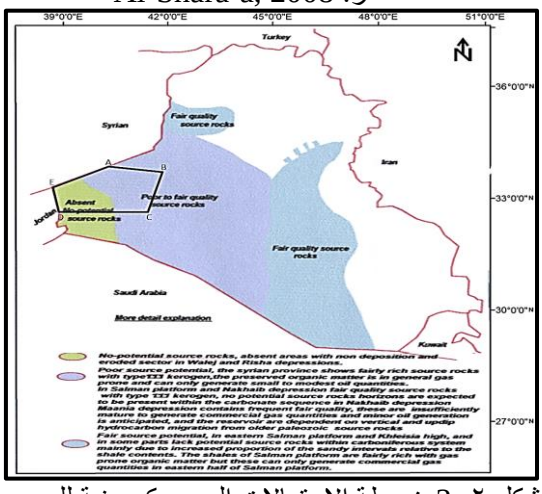
The Devonian section was penetrated in the Akkas and Khulaisiya fields in western Iraq, and this section is missing in all areas of Jordan, most of the Syrian lands, and some areas of the Rutba plateau. The Devonian period in the study area, the Rutba plateau, and the Ma'ani depression are considered to have weak potential as source rocks for oil generation, Figure (2-9). The organic carbon content of the Devonian shale is about (3.44)% in the (Khulaisiya-1) well and (1.49)% in the (Akkas-1) well, and they are of continental origin, (AL-Haba, 1991). The organic materials contain small pieces or fragments of wood, catenosis, pollen and spores, which are often continental in origin (AL-Haba, 1994). Therefore, they are more suitable for generating gases than oil if they reach the appropriate thermal maturity level. However, most geochemical indicators confirm that these layers fall within the immature range, and the production index (PI) was very low in the Khulaisiya-1 and Akkas-1 wells, indicating immaturity. 2-4-4 Carboniferous rocks

The facies of this age tend to be good quality source rocks in the eastern part of the Salman

High and some western areas of the Western Desert. The study area has a weak to acceptable probability as source rocks. The Carboniferous sequence in the western Iraqi desert shows an acceptable probability as source rocks, as in the Khulaisiya High, and some areas east of the Salman Depression are acceptable in terms of organic content and may generate economic quantities of gas, Figure (2-10), (Al-Shara´a, 2008).



شكل ٢- 2 خريطة الاحتمالات الهيدروكربونية للصخور المصدرية لمجموعة اورا (عصر الديفوني)
المصدر: Al-Shara´a, 2008



شكل ٢- 3 خريطة الاحتمالات الهيدروكربونية للعصر الكاربوني موضح عليها منطقة الدراسة
المصدر: Al-Shara´a, 2008

2-4-5 Permian Generating Rocks

Geochemical analyses conducted on the Upper Permian shale rocks within the Ka'ra Formation in the West Al-Kifl-1, Atshan-1 and Jabal Qand-1 wells show the presence of organic materials of continental origin with a TOC rate of about (1.1) % WT, ((Al-Haba, 1994). As for the geochemical analyses conducted on the Jiyaziri Formation in the Diwan-1, West Al-Kifl-1 and Atshan-1 wells, they showed a reasonable hydrocarbon potential, and partially in the shale section

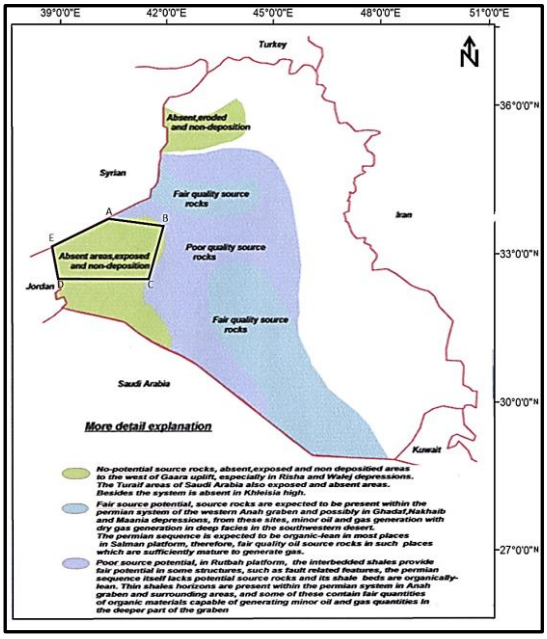


Figure 2-11 Hydrocarbon potential map of the Permian period showing the study area
Source: Al-Shara'a, 2008

Conclusions

1. The Western Desert is considered one of the important and promising areas because it contains hydrocarbons from oil and gas, as it is characterized by generative rocks that contain a good amount of organic matter in the formation of Akkas (Silurian) and Khabur (Ordovician).
2. The areas of low density of the liners represent height areas in the sedimentary basin, where fractures are formed with high density around these heights because of the differential pressure of sediments on these heights.
3. The stratigraphic trap sites discovered in the current study are on the edges of the ancient paleo high elevations.

Recommendations

- Conducting a three-dimensional seismic survey to determine the stratigraphic shape and its extensions with high accuracy.

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