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Hydrocarbon Prospectivity of Al-Sirhan Basin, Southeast Jordan

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ABSTRACT

Al-Sirhan area in southeast Jordan is studied for its hydrocarbon potentiality. Petrophysical studies including porosity, permeability, water saturation, and hydrocarbon saturation are done using wire line logs for candidate reservoirs. Total organic carbon analysis is done for two candidate source intervals. Seismic investigation is also done using seventeen seismic sections that cover almost the central and eastern part of the area. Finally, closures, reserves, and proposed migration pathways of hydrocarbons are studied in order to assess the hydrocarbon potentiality of the study area.

Within the Cambrian sequence, Salib Formation is found to contain good porosity due to partial dissolution of feldspars, very low permeability, and high water saturation. This formation is capped by the shales of the overlying Burj Formation. Possible source rock is the carbonates of the Burj Formation. Several types of closures with good capacities exist within the Salib Formation. The major risks, when considering Salib Formation as a target for petroleum exploration, are low TOC content of the source rock, low permeability and high water content of the reservoir rock.

Within the Ordovician and Silurian sequence, the glacially deposited Trebeel Formation is found to contain good porosity, low permeability, and low water saturation. This formation is caped by the shales of the overlying Batra Formation. Several intervals contain good source rocks within this system. These are the shales of Sahl as Suwwan Formation, the shale layers at the upper part of Umm Tarifa Formation, and the shales of the overlying Batra Formation. TOC analysis in the present study proved that Hiswa Formation might be considered good source rock. Organic carbon analysis carried by several petroleum companies indicated the high TOC content of the lower part of Batra Formation and the upper shale layers of Umm Tarifa Formation (Paleoservices, 1989). Several types of closures are found within Trebeel Formation. All the main closures were tested by wells and found to be almost dry. Thus, the major risks when considering Trebeel Formation as a target for petroleum explorations, are the low permeability of the reservoir rock, and the lack of potential untested closures.

The only way that might cause filling the closures of the study area with hydrocarbons is from the source rocks within the Al-Sirhan Graben in Saudi Arabia. As the graben formed deeper depositional environment during the Paleozoic Era, better source conditions exist within the graben. Thus, hydrocarbons might be generated in the graben and migrated through the Jordanian borders to reach Al-Sirhan closures which exist at higher elevations. This scenario forms high risk as the pathway is interrupted by several growth faults that provide possible paths for hydrocarbons to escape to the surface. Accordingly, the study area is classified as high risk area for petroleum exploration.

Keywords: Al-Sirhan Basin, Hydrocarbons, Trap, Closure, Source rock, Seal rock.

1. INTRODUCTION

Al-Sirhan Basin, in southeast Jordan (Fig. 1), is chosen to be assessed for its hydrocarbon potential. Many reasons stand after choosing this basin. First, is the vigorous hydrocarbon exploration activity in the area which was carried out by the Natural Resources Authority (NRA) and several foreign petroleum companies. These activities resulted in an abundant availability of seismic reflection and stratigraphic data. Second, is the availability of a thick Early Palaeozoic succession that reaches 4000 m comprised of both source

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and reservoir rocks. This situation leaded to the formation of uneconomic oil found in well WS-4. Finally, is the existence of structural traps in the form of down faulted blocks, horsts, and anticlines that were formed during the Palaeozoic Era, the Mesozoic Era, or later during the Tertiary.

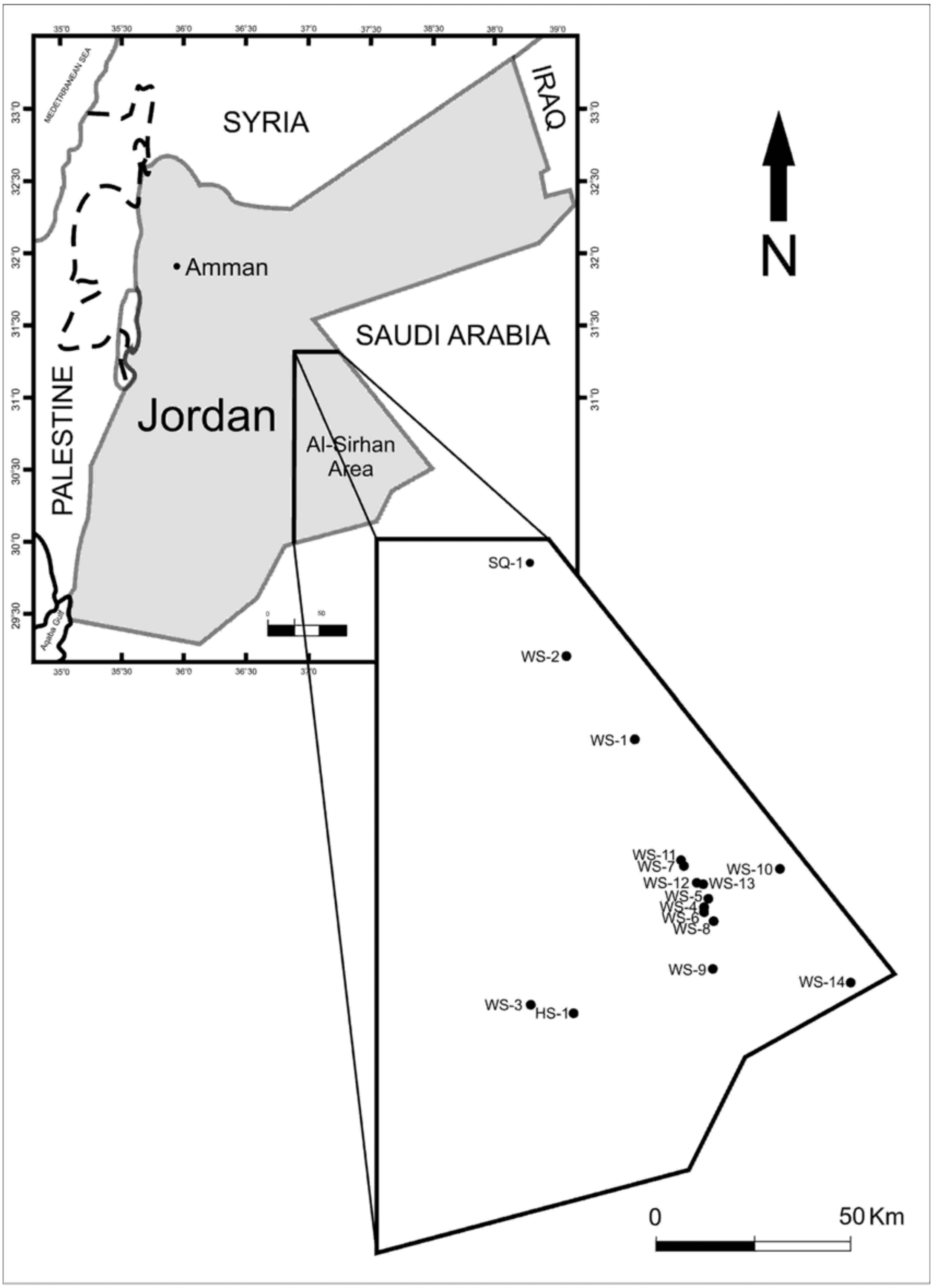

Figure 1:Location of Al-Sirhan area and its wells.

Table 1: Lithostratigraphy of the subsurface Palaeozoic rocks in Al-Sirhan area (modified after Masri, 1987, 1988, Powell, 1989, Andrews, 1991, Abed, 2000).

Group	Formation	Period	
Khreim	Alna	Silurian	Wenlock Llandovrian
			Llandovrian
	Batra		Llandovrian Ashgillian Caradocian
	Trebeel Umm Tarifa	Ordovician	Llandelian
	Sahl as Suwwan		Llanvirian
Ram	Amud		Arenigian
			Tremadocan
	Ajram	Cambrian	Late Cambrian
	Burj		Early Middle Cambrian
	Salib		Early Cambrian
Umm Ghaddah Formation		Infra-Cambrian	
Araba Complex		600-540 Ma	
Aqaba complex		800-600 Ma	

Al-Sirhan basin comprises the southwestern part of the Azraq-Sirhan depression which is situated in northwest Saudi Arabia close to the Jordanian border. Sixteen wells were drilled in the area covering the southern and the eastern part of the basin along the border with Saudi Arabia (Fig. 1).

2. AIMS OF STUDY

The present study aims to investigate the petrophysical characteristics (porosity, permeability, water saturation, and oil saturation) of every formation in the stratigraphic sequence in the basin which will lead to evaluate the existence of potential source, reservoir, and seal rocks in the basin. Another aim is to assess the existence of closures within the basin using seismic lines interpretation and to estimate the depth and reserve of each closure.

3. GEOLOGICAL SETTING

At the end of the Precambrian, metamorphic and granitic rocks formed in the basin due to the collision between the African and Afif Plates (Bakor et al., 1976, Al-Shanti, 1993, Abed, 2000). This event was followed by an extensional phase in the basin and the whole region resulted in the formation of the Najd Fault System which extends NW – SE (Al-Shanti, 1993). Thus, northwest elongated basins formed in Arabia such as the Azraq-Sirhan Depression. Volcanic activity contemporized the extensional event in the basin. Accordingly, thick basaltic andesite lava flows covered the Al-Sirhan basin overlying the granitoids of Aqaba Complex and underlying the Palaeozoic sedimentary strata (Abul Khair, 2007).

During the Palaeozoic Era, Al-Sirhan Basin was part of the stable shelf at the northern part of Gondwanaland supercontinent. It was located on the southern limit of the Tethys Ocean (Beydoun, 1988, Al-Shanti, 1993). Sedimentation was controlled by the interplay between sediment input from the Arabian-Nubian Shield in the south and periodic transgression of the Tethys Ocean across the shelf from the north. The Palaeozoic succession in the basin was divided by Masri (1988), Powell (1989), and Andrews (1991) into two groups, the oldest Ram Group, and the youngest Khreim Group

(Table 1). During the deposition of Ram Group (Early Cambrian to Middle Ordovician), braided and meandering rivers delivered clastic influx from the Arabian Shield in the south to the Tethys in the north (Bender, 1974, Amireh, 1987, Powell, 1989, Abed, 2000, Abed, 2005). These rivers resulted in the deposition of thick, reaching 2300 m fluvial sediments with short marine ingressions (Amireh, 1987). From Middle Ordovician to Early Upper Silurian, a major marine transgression of the Tethys occurred on the basin resulting in the deposition of 1700 m of marine clastic sediments (Khreim Group). The depositional environment ranges from tidal flats to open marine interrupted by a fluvioglacial environment in the Upper Ordovician (Andrews, 1991, Abed et al., 1993, Amireh et al., 1994, 2001, Turner et al., 2005).

Although not presented in the stratigraphic section of the basin, around 2000 m of clastic, mainly marine, sediments deposited from Early Upper Silurian to Lower Upper Devonian (Abul Khair, 2007). These deposits were eroded from the basin due to the regional uplift in the Middle Carboniferous which is called The Hercynian Orogeny (Konert et al., 2001, Haq and Qahtani, 2005). This uplift resulted from a regional anticline called "geanticline of the Helez area" which was formed during the Middle Carboniferous. The center of this geanticline is near Gaza in south Palestine (Gvirtzman and Weissbord, 1984). This orogeny resulted in an easterly tilting of the Lower Palaeozoic strata in Jordan and erosion of several thousands of meters of the underlying deposits (Bender, 1974, Beydoun, 1988, Abed, 2000).

During the rest of the Palaeozoic Era and most of the Mesozoic Era, Al-Sirhan area was forming a paleo-high, compared with the northern part of Jordan, as no Carboniferous to Jurassic deposits are found within the basin. In the Early Cretaceous, and due to the continuation of the Mediterranean rifting and tectonic subsidence of Al-Sirhan basin, reduced Early Cretaceous fluvial deposits (Kurnub Group) covered the basin. By the Late Cretaceous, Al-Sirhan area subsided to the level that the NeoTethys prograded and covered the basin with 790 m thick carbonate sequence of Upper Cretaceous and Tertiary age in the northern part of the basin and decreasing to 260 m in the south. By the end of the Eocene, Al-Sirhan area was uplifted due to the regional uplift that affected Arabia which was accompanied with the beginning of the formation of the Arabian Plate and the Dead Sea Transform (Bender, 1974, Abed, 2000, Abed, 2005).

4. METHODOLOGY

In order to determine potential reservoirs in the basin, porosity, permeability, water saturation, and hydrocarbon saturation were estimated for each formation from neutron, sonic, density, and spontaneous potential logs using the equations of Asquith and Gibson (1982). Total Organic Carbon (TOC) content was determined for Burj and Sahl as Suwwan Formations in order to determine the potentiality of these formations as source rocks. Seismic reflection sections were analyzed and time structure maps were drawn for the main reservoir targets using 16 seismic lines, and Vertical Seismic Profiles (VSPs) displayed within five different wells.

5. RESULTS

The potential hydrocarbon plays of Al-Sirhan area are divided, in the current study, into two systems. These are the Cambrian play system, and the Ordovician - Silurian play system. Aspects that control hydrocarbon potentiality will be discussed in details for each hydrocarbon play system. These aspects will include source, reservoir, and seal rock characterizations, types of trapping, description of closures, and reserves calculations.

5.1. The Cambrian Play System

The proposed Cambrian play system is composed of the carbonate Numayri Member of the Burj Formation as a source rock, Salib Formation as a reservoir rock, and the Tayan Member of the Burj Formation as a seal rock.

5.1.1. Source Rock

The major marine interval within the Cambrian sequence in Al-Sirhan area is the Middle Cambrian Burj Formation. Using microfacies analysis, a depositional environment of supratidal to subtidal is given for the carbonate interval within the formation (Powell, 1989, Abu Qudaira, 1996, Abul Khair, 2007). Although the formation was considered by Haq and Qahtani (2005) a potential source interval in the Arabian Region, Burj Formation hasn't been proved in any country to be a source rock for any hydrocarbon play. Samples within Burj Formation were examined for its organic carbon content and were found to contain TOC content up to 0.3% which is negligible (Hunt, 1996). Accordingly, the carbonate interval of Burj Formation is considered a high risk source rock as no direct evidence proved its potentiality.

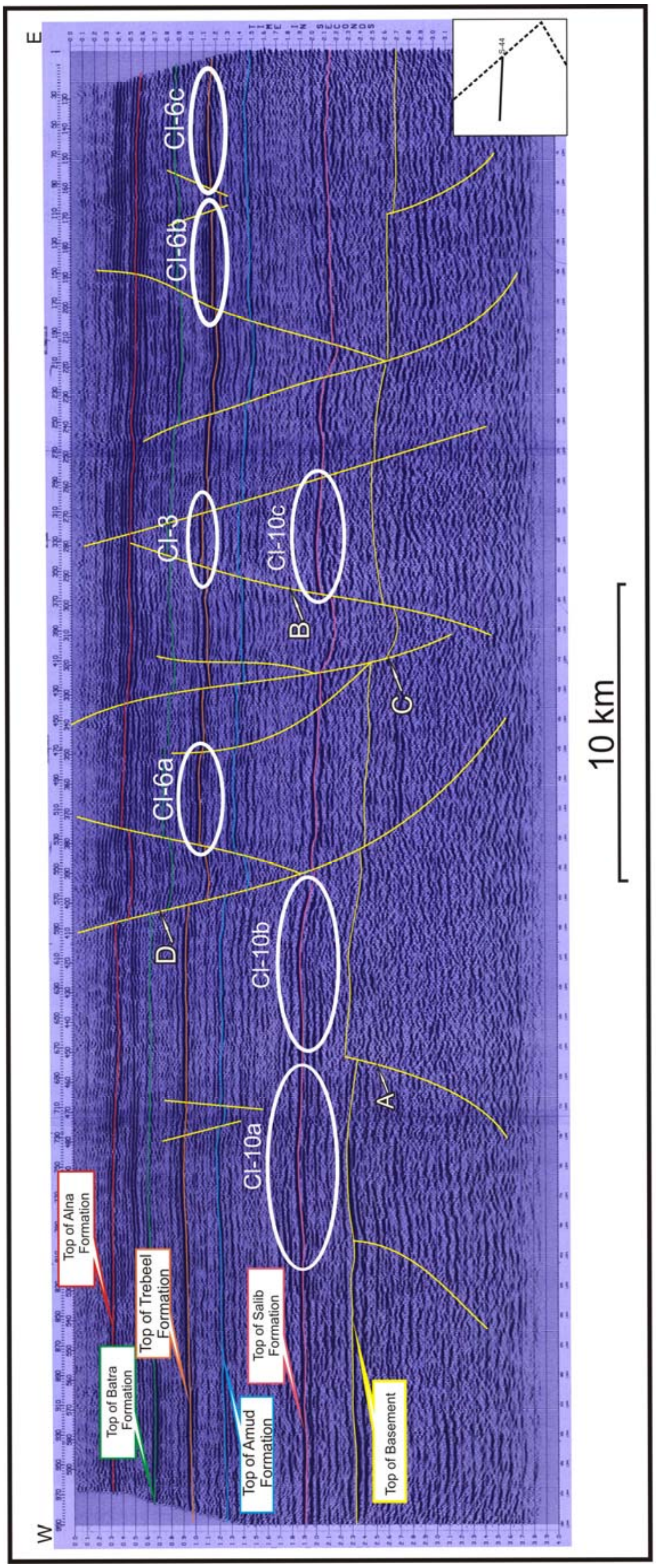

Figure 2: Seismic line S-44 showing different interpreted reflectors, small horst structures closures, compactional fold closures, and faults. A= Precambrian faults associated with Najd Fault System, B= reactivated faults during Late Paleozoic showing decreasing downthrown towards younger sediments and breaking only Paleozoic rocks, C= reactivated faults during the Tertiary showing decreasing downthrown towards younger sediments and breaking all the sequence, D= Tertiary fault breaking the whole sequence showing decreasing downthrown towards older sediments. Ellipses indicate proposed closures.

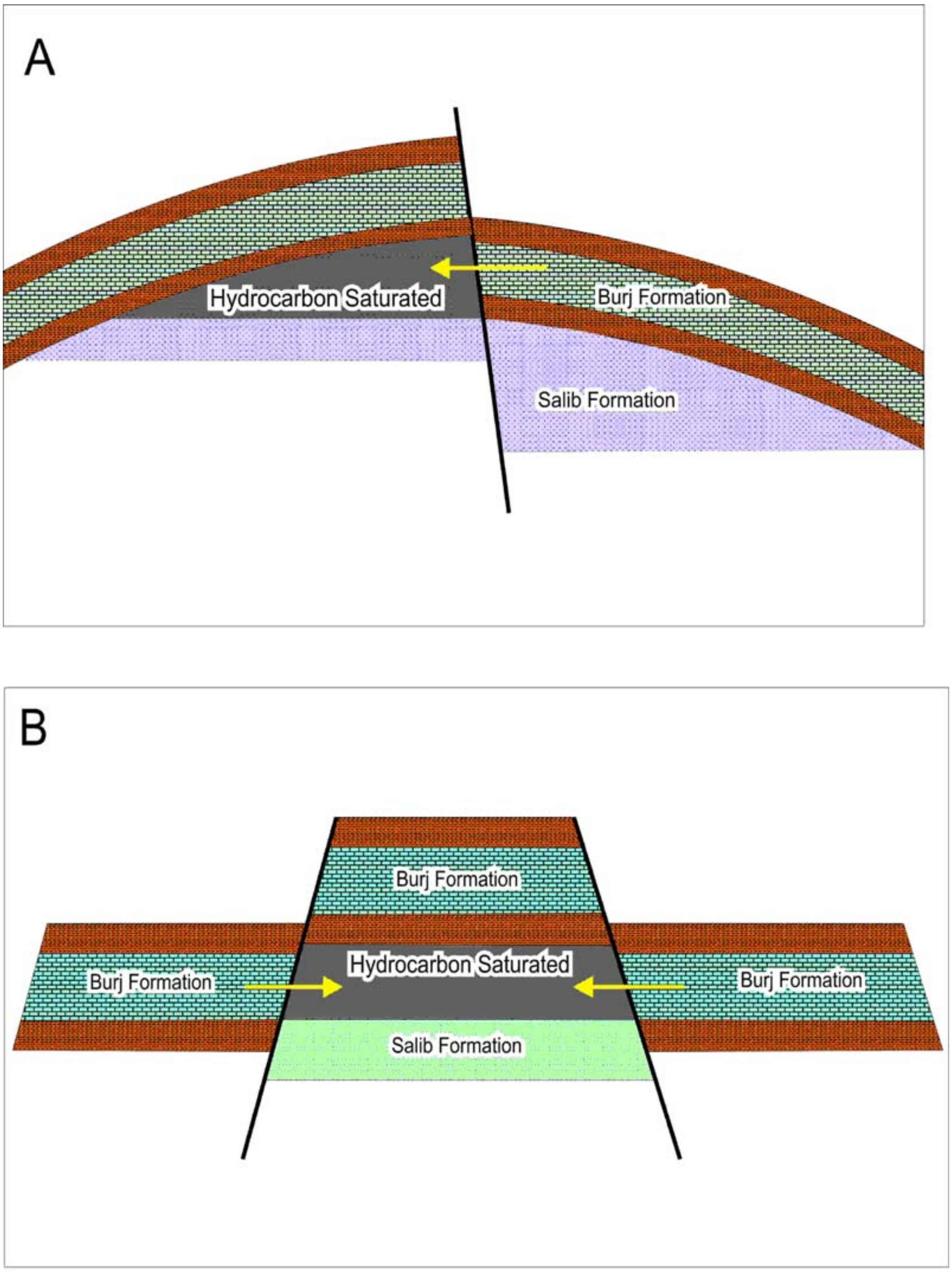

Figure 3: Theoretical configuration of traps related to tensional faults within Sirhan Basin.

5.1.2. Source Rock Maturity

Illite crystallinity is used, in this study, for determining hydrocarbon maturity as no vitrinite exists in the pre-Middle Silurian age (Kubler, 1967, Weaver, 1960, Guthrie et al., 1986). Vitrinite reflectance values calculated using sharpness ratio index (SR) range between 1.47 and 1.8 Ro%. These values indicate that the source rock entered the stage of the end of oil generation and didn't reach the stage of the end of oil preservation (within the catagenesis stage) (Tissot and Welte, 1984; Hunt, 1996). Thus, if the Burj Formation is considered as a source rock, oil has been generated from the formation's kerogen and was preserved.

5.1.3. Reservoir Rock and Its Characteristics

The main reservoir within the Cambrian sequence is the fluvial sandstone Salib Formation. Although quartz overgrowth, illite and kaolinite neoformation strongly reduced porosity of the formation, internal dissolution of feldspar is the major diagenetic process that enhanced porosity. Petrophysical calculations proved that the formation contains several intervals of clean sandstones up to 145 m and porosities up to 13.2%. This fair to good porosity made these intervals potential reservoirs.

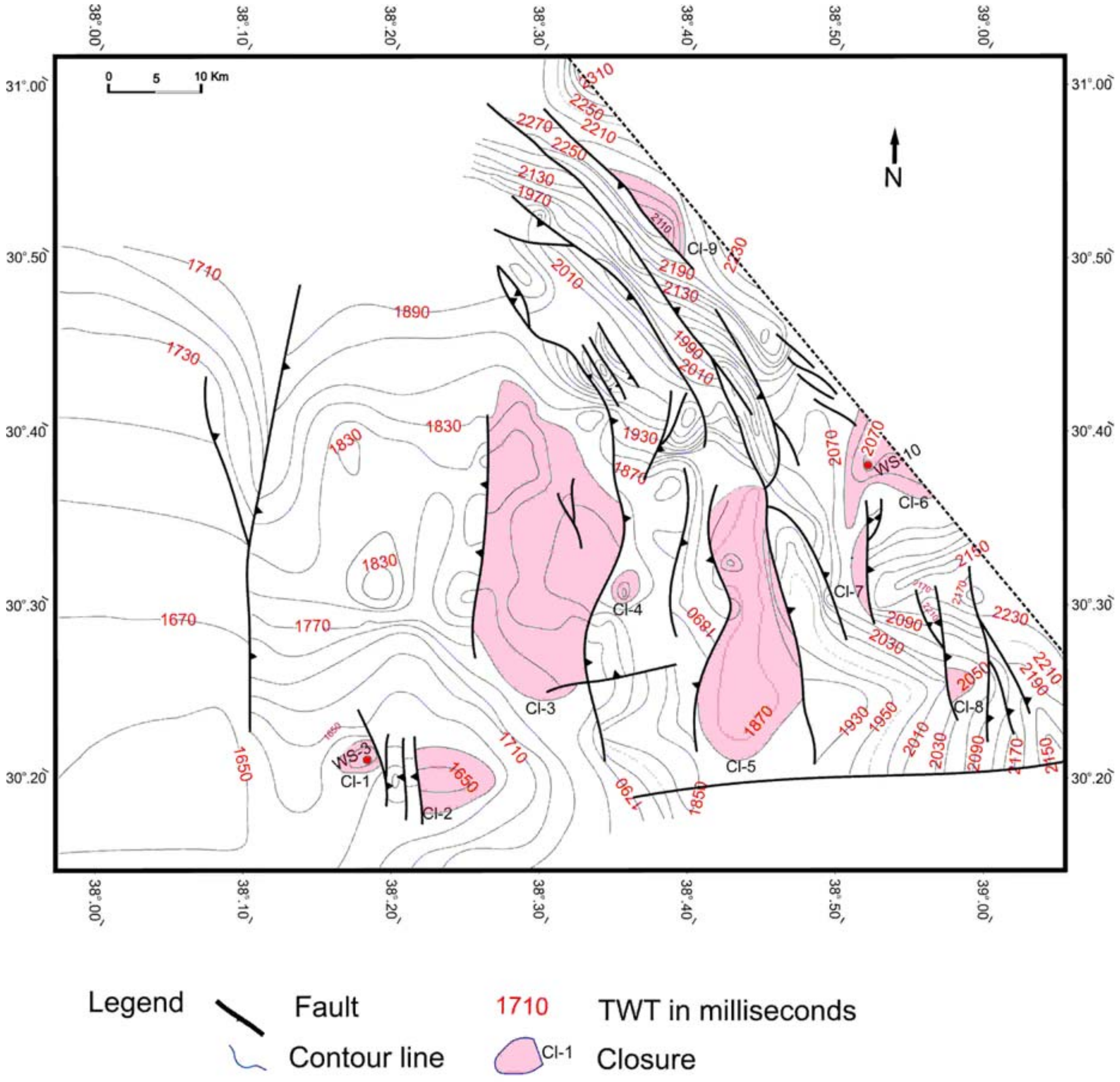

Figure 4: Time structure map for the top of Salib Formation.

Using Asquith and Gibson equations (1982), water saturation (Sw) is calculated for the interval that extends from depth 3745 to 3890 m of Salib Formation and is found to be 75%. Thus, water saturation represents a high risk within the formation. Permeability measurements, for core samples from the depth interval 3712 to 3719 m in well WS-3, were carried out by OMV (1990) and was found to be 0.35 to 0.93 md. On the other hand, permeability calculations for several intervals within Salib Formation using wire line logs gave the similar negligible values. Thus, permeability of the formation represents another high risk.

5.1.4. Seal Rock

The proposed seal rock for the Cambrian play system is the lower member of the Burj Formation (Tayan Member) which directly overlies the upper 145 m clean sandstone interval of Salib Formation. This member is composed of 23 m shales to fine siltstone forming impermeable media that prevent upward migration of hydrocarbons (Selley, 1998).

5.1.5. Trap Styles

The only type of traps that exists within the Cambrian system in Al-Sirhan area is the structural type.

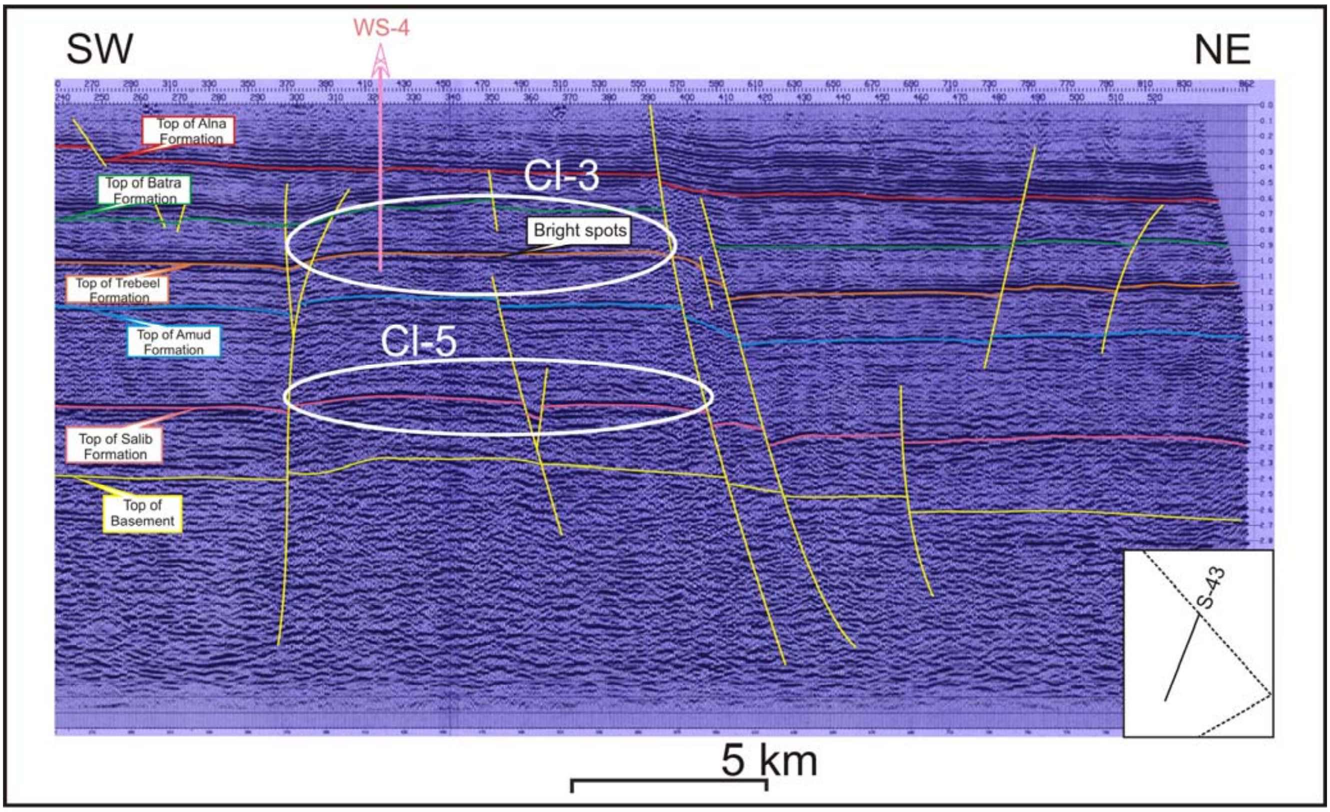

Figure 5: Seismic line S-43 showing different interpreted reflectors and closure-5 within Salib Formation and 3 within Trebeel Formation (horst structure).

5.1.5.1. Traps Related to Tensional Faults

These traps are either, downfaulted blocks along normal faults, or uplifted blocks between two normal faults dipping away from each other forming horst structures (Fig. 2). Along these types of faults, the carbonates of Numayri Member, which are considered in this study as a source rock, are juxtaposed and brought at the same level with the underlying Salib Formation. Thus the hydrocarbons will migrate laterally from the source rock to the reservoir and sealed by the overlying shale of Tayan Member (Figs. 3 A and B). The main restriction within these trap types is that the downthrown of the fault must not exceed 100 m (the thickness of Burj Formation). If so, the hydrocarbons will escape from Salib Formation to the overlying Ajram Formation. Thus, the hydrocarbons will be dispersed within the formation as no seal rock exists within or overlying Ajram Formation. Another restriction within this trap type is that most faults are growth faults (i.e. Precambrian faults reactivated several times) (Abul Khair, 2007). In most instances, these types of faults are not sealing because they were associated with slivers of permeable sand. Accordingly, migration of hydrocarbons occurs up the fault plane and across it (Weber et al., 1980, Selley, 1998).

5.1.5.2. Traps Related to Compactional Anticlines

Compactional anticlines formed due to ordinary sedimentation above deep-seated horst structures within the basement rocks rather than due to tectonic forces. These types of anticlines form good closures within sediments that directly overly the basement rocks and the closures disappear upward (Selley, 1998). As Salib Formation overlies the Aqaba complex, several compactional traps exist in Al-Sirhan Basin forming potential closures (Fig. 2).

5.1.6. Closures

Nine different closures have been identified within the time structural map of Salib Formation (Fig. 4). These closures are either horst structures like closures 3 and 5 (Fig. 5), compactional anticlines like closure 2, or downfaulted blocks like the rest of the closures.

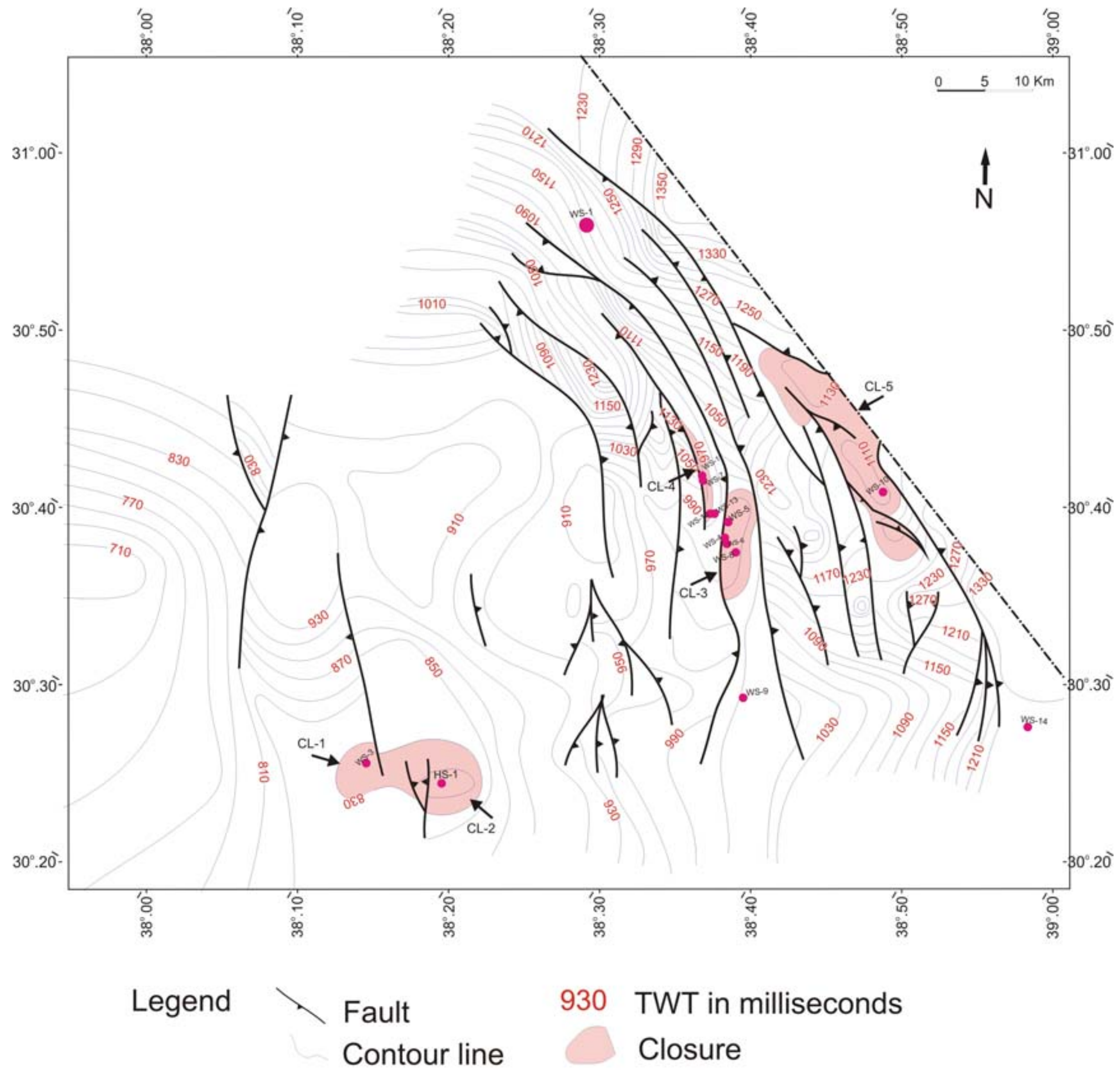

Figure 6: Time structure map for the top of Trebeel Formation.

Several gentle compactional folds overly deep horst structures and form important closures but with thicknesses (the distance between the crest and the spill point) that doesn't exceed 20 milliseconds (Fig. 2). The main possible charge for these closures is from the Burj Formation and along the downfaulted blocks at the eastern and northeastern part of the basin. As the area by end of the Precambrian was dominated by horsts and inter-mountain basins (Al-Shanti, 1993), the Palaeozoic sequence accumulated above the horsts with fold limbs dipping east and west and elongated northwest above the Precambrian horsts (Fig. 2).

5.1.7. Reserve Calculation

The percentage of moveable hydrocarbons is calculated from Asquith and Gibson`s equations (1982) by dividing water saturation of uninvaded zone Sw over water saturation of invaded zone Sxo. It was found that within Salib Formation, only 50% of the existing hydrocarbons are moveable and thus can be extracted. The reserve within every closure is calculated also depending on the area of the closure as seen in Table (2). According to the previous volumes, the nine major closures contain oil up to 1735 million cubic meters. This quantity equals to ten billion barrels.

5.2. The Ordovician-Silurian Play System

The proposed Ordovician-Silurian play system is composed of Sahl as Suwwan and Batra Formations together with the upper shale layers of Umm Tarifa Formation as source rocks, Trebeel Formation as a reservoir rock, and Batra Formation as a seal rock.

5.2.1. Source Rock

Two major marine transgressions covered the area with relatively deep depositional environment capable to accumulate organic rich sediments. The first marine transgression is marked by the shale layers of Sahl as Suwwan Formation. It is correlated with maximum flooding surface MFS O30 (Sharland et al., 2001) and dated 469 Ma (Llanvirian). This interval is proved to contain good organic carbon content exceeding 1% and thus can be considered potential source interval (Hunt, 1996). This interval wasn't considered a source rock within any Arabian country except in Saudi Arabia. This indicates that the continental shelf of the Tethys contained restricted basins, such as Al-Sirhan Basin, which gave rise to restricted circulation and thus better source conditions. Accordingly, this interval can be considered source interval only in the Al-Sirhan area and in the areas close to it.

The second major marine transgression within the basin and the whole Arabian Region was during the Early Silurian (Rhuddanian age), MFS S10, 440 Ma (Sharland, et al., 2001). Anoxic water bottom conditions in the sediment-starved basin resulted in the preservation of the organic rich shales of Batra Formation–the prolific Silurian ‘hot shale’ (Konert et al., 2001, Armstrong et al., 2005). Within Al-Sirhan Basin, this interval is proved to contain high organic carbon content especially the lower 20 m of the formation which contain organic carbon that reaches 6.7% (Paleoservices, 1989, Konert et al., 2001, Haq and Qahtani, 2005).

On the other hand, organic carbon content determination for the upper shale layers of Umm Tarifa Formation was carried out by Paleoservices (1989) and OMV (1990) in well WS-2. Two samples gave TOC values that exceeded 1%. Accordingly, this interval can be considered source interval but needs more investigation.

5.2.2. Source Rock Maturity

Vitrinite reflectance values calculated using sharpness ratio index (SR) for Sahl as Suwwan Formation range between 0.64 and 0.83 Ro%. These values indicate that the source rock entered the oil generation window (Tissot and Welte, 1978), and thus heavy oil might have been generated (Selley, 1998). On the other hand, vitrinite reflectance values calculated using sharpness ratio index (SR) for Batra Formation range between 0.67 and 1.0 Ro%. These values indicate that Batra Formation as a source rock entered the oil generation window (Tissot and Welte, 1978), and thus heavy oil might have been generated (Selley, 1998).

Determination of maturation levels for the Batra Formation was carried out by OMV (1990) using colour changes of Chitinophosphatic materials of probable graptolitic origin. These values are found to be 1% in the east in well WS-4, 0.7% in well WS-3, and between 0.45 and 0.55% in the west, in well Al Jafr-1. Accordingly, a general trend of increasing maturation from west to east exists. This trend of maturation gives evidence that the eastern and northeastern parts of the basin were buried to larger depths than the western parts. And thus, during most of the Palaeozoic Era, Al-Sirhan area was forming a basin giving rise to larger thicknesses of the Palaeozoic sequence to be accumulated and thus better source conditions compared with the adjacent areas (Abul Khair, 2007).

5.2.3. Reservoir Rock

The most potential reservoir rock within the Ordovician-Silurian play system is the Trebeel Formation that directly underlies Batra Formation. Using wire line log, this interval proved, in the current study, to contain fair to good porosity up to 10.4 % in well WS-3. The clean sandstone was interpreted by Paleoservices (1989) Andrews (1991) to be deposited during the glacial episode that affected the Arabian Region in the Late Ordovician (Ashgillian). The base of this formation represents a major unconformity dated 445 Ma (base of AP3) (Haq and Qahtani, 2005). This reservoir represents the target for all petroleum exploration in Jordan as the light oil in well WS-4 was discovered within this interval. Other possible reservoirs within the system are the sand intervals within Umm Tarifa Formation. These intervals proved to contain fair to good porosity up to 10%. The charge for these reservoir intervals might be from the overlying Batra Formation or the underlying Sahl as Suwwan Formation or may be from the organic rich shale layers within the formation and sealed by the same shale layers within the formation. Thus, these sandstones with the intercalated shale layers form possible stratigraphic traps.

Water saturation values calculated for the major reservoir within this play system (Trebeel Formation) indicated that the formation is saturated with 54% water. On the other hand, permeability calculations proved that the formation contains poor permeability in well WS-3 up to 0.53 md. It is believed that this low permeability is responsible for the uneconomic oil production in well WS-4.

5.2.4. Seal Rock

The shale layers of Batra Formation that cover the whole basin provide an excellent seal for the underlying reservoir of Trebeel Formation. These shales are considered both source and seal rocks for the Ordovician-Silurian play system.

5.2.5. Trap Styles

The same types of traps that exist within the Cambrian system are seen in this system. Along faults, the shale of Batra Formation is juxtaposed and brought at the same level with the underlying Trebeel Formation. Thus the hydrocarbons will migrate laterally from the source to the reservoir and sealed by the overlying shale of Batra Formation.

5.2.6. CLOSURES

Five different closures have been identified within the time structural map of Trebeel Formation (Fig. 6). These closures are fault related closures and were tested by wells WS-3, HS-1, WS-4, WS-7, WS-11, WS-12, WS-13, and WS-10. All wells were found dry except for the light oil (API 39) in well WS-4 (Paleoservices, 1989). It is clear on seismic section that the Trebeel Formation contains the so called "bright spots". Bright spots are amplitude anomalies or high amplitude reflections associated with hydrocarbon accumulations in some areas (Hart, 2000). These bright spots can be seen at the top of the horst structure and at the area to the southwest (Fig. 5). Thus, it is clear that the hydrocarbons were migrated from the northeastern part of the basin to the southwestern part and trapped within this horst structure. Two reasons made this closure the only one to contain hydrocarbons. The first one is that the downthrown of the eastern fault exceeds 200 milliseconds. This time when converted to thickness becomes 290 m. Thus most of Batra Formation is juxtaposed and brought at the same level with Trebeel Formation. Accordingly, the whole thickness of Batra Formation charged the horst structure with relatively good quantities of hydrocarbons. The second reason might be the existence of a normal fault at the middle part of the closure which breaks the Formations from Umm Ghaddah to the middle part of Umm Tarifa Formation (Fig. 5). This fault provided a path for another charge from the lower Burj and Sahl as Suwwan Formations. Unfortunately, the production of the reservoir was uneconomic (21 bls/d). This negligible production forced the NRA to close the well (NRA, 2004).

Table 2: Closures of the Cambrian and Ordovician – Silurian play systems and its oil reserves.

System	Closure	Area (km^2)	Reserve (million m^3)
Cambrian	1	20	43.5
=	2	30	65.25
=	3	450	978.75
=	4	10	21.75
=	5	200	435
=	6	40	87
=	7	10	21.75
=	8	8	17.4
=	9	30	65.25
Ordovician - Silurian	1	20	14.4
=	2	80	57.6
=	3	50	36
=	4	20	14.4
=	5	125	90

Several gentle compactional closures and small horst traps are seen in seismic sections especially to the east and northeast. Five horst structures having widths ranging between 5 and 10 km are found. These closures might be charged from the underlying Sahl as Suwwan Formation through fault planes or from the overlying Batra Formation through lateral migration along downfaulted blocks to the northeast. Examples of these traps are closure-6a, closure-6b, closure-6c (Fig. 2). Accordingly, these traps are considered the most significant and potential reservoirs within the basin.

5.2.7. Reserve Calculation

Calculating oil reserves within the five closures of this play system is done using the same procedure as the previous system. It is found that within Trebeel Formation, 76% of the existing hydrocarbons are moveable and thus can be extracted. The calculated reserves within every closure of the system are introduced in Table (2). According to the previous volumes, the five major closures contain oil up to 212.4 million cubic meters. This quantity equals to 1.3 billion barrels.

6. DISCUSSION AND CONCLUSIONS

Within the Cambrian play system, low TOC content of the source rock, low permeability and high water saturation of the reservoir represent the major risks when considering this system as potential one. Also, intense faulting within the basin provides possible pathways for upward escape of hydrocarbons. On the other hand, the major advantage of this system is the availability of several large untested closures.

Within the Ordovician-Silurian play system, the low permeability of the proposed reservoir, the lack of untested closures, and the intense faulting, provide disadvantages when considering this system as potential one.

As stated earlier, Azraq-Sirhan Graben, in Saudi Arabia, was forming a basin during most of the Phanerozoic time. Thus, during the deposition of Burj, Sahl as Suwwan, and Umm Tarifa Formations, this graben was forming deeper depositional environment within the continental shelf of the Paleo-Tethys compared with the Al-Sirhan area in Jordan. Accordingly, organic rich sediments with higher TOC content might be deposited within this graben in Saudi Arabia.

As the Palaeozoic sequence in the study area appears within the seismic sections to be dipping towards the graben in Saudi Arabia, possible pathway for any generated hydrocarbons within the graben might be towards Al-Sirhan area. Thus, if Burj, Sahl as Suwwan, Umm Tarifa, or even Batra Formations generated hydrocarbons, the major way for the secondary migration of these hydrocarbons will be to the Al-Sirhan area in Jordan as the area exists at higher elevation than the graben. Accordingly, the closures within the Cambrian play system might be sourced from the hydrocarbons that are generated in the graben and migrated to the Al-Sirhan area.

Another advantage for considering this migration pathway is the existence of intensive faulting especially towards the graben. These faults are normal faults that might result in bringing the Palaeozoic proposed source rocks at the same level with the reservoir intervals. Thus, the primary migration from the source to the reservoir might be laterally through these normal faults. Also, the secondary migration towards possible traps might be to the Al-Sirhan traps in Jordan. The main disadvantage in this scenario is that the normal faults that exist within the pathway of the secondary hydrocarbon migration are growth faults. This type of faults is considered possible path for upward escape of hydrocarbons towards the surface. Thus possible loss of these hydrocarbons might occur within these faults (Selley, 1998).

According to the previous discussion, Azraq-Sirhan Graben might be considered the source and the kitchen for generating potential hydrocarbons, and Al-Sirhan area in Jordan is the trap for these hydrocarbons. But, relatively small sizes of closures, low reservoir quality, and the existence of growth faults within the pathway of the hydrocarbon migration represent very high risk to consider Al-Sirhan area as a potential area for petroleum exploration.

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الاحتمالات الهيدروكربونية في منطقة السرحان الواقعة جنوب الأردن

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ملخص

لقد تم دراسة الاحتمالات الهيدروكربونية في منطقة السرحان الواقعة جنوب شرق الاردن. تمت دراسة جميع التكاوين الجيولوجية في حوض وادي السرحان من ناحية الخصائص الفيزيائية للصخور والتي تضمنت المسامية، النفاذية، نسبة الإشباع بالماء ونسبة الإشباع بالنفط باستخدام المجسات البئرية لجميع التكاوين التي يمكن أن تكون خازنة للبترول. تم حساب كمية الكربون العضوي لتكوينين في منطقة الدراسة بهدف التوصل إلى احتمالية كونهما صخور مصدر أم لا. تم عمل الدراسات الزلزالية باستخدام ستة عشر مقطعاً زلزالياً تغطي معظم وسط وشرق منطقة الدراسة. كما تم تحديد المكامن البترولية المحتملة والاحتياطي في كل مكمن وطرق الهجرة المحتملة من أجل تقييم الاحتمال البترولي في المنطقة.

في نظام الكامبري، وجد أن تكوين سلب يحتوي مسامية جيدة، بسبب الإذابة الجزئية لمعدن الفلسبار، نفاذية منخفضة، ومحتوى عالٍ من الماء. إن تكوين سلب مغطى بالغضار الموجود في تكوين البرج الذي يعلو تكوين سلب. صخر المصدر المحتمل لهذا النظام هو الحجر الجيري في تكوين البرج. تم العثور على العديد من المكامن وبقدرة تخزينية عالية في تكوين سلب. لكن الخطورة الرئيسية في اعتبار تكوين سلب كهدف للتنقيب عن البترول هو انخفاض المحتوى العضوي في صخر المصدر، انخفاض النفاذية، وارتفاع المحتوى المائي.

في تتابع العصرين الأوردوفيشي والسيلوري، فقد وجد أن تكوين تريبيل يحوي مسامية جيدة، نفاذية قليلة، ومحتوى مائيا قليلاً. هذا التكوين مغطى من أعلى بالغضار التابع لتكوين البترا الذي يعلو تكوين تريبيل. تم العثور على العديد من الوحدات التي تحتوي على صخر مصدر جيد في هذا النظام وهي: الغضار في تكوين سهل الصوان، الغضار في الجزء العلوي من تكوين أم طريفة، والغضار في تكوين البترا الذي يعلو تكوين تريبيل. قياسات الكربون العضوي وقد أثبتت أن تكوين سهل الصوان يمكن اعتباره كصخر مصدر. أما الصخرين الآخرين، فقد قامت العديد من شركات البترول بدراسة المادة العضوية فيهما وتبين أنهما يعتبرا صخور مصدر جيدة (Paleoservice, 1989). تم العثور على العديد من المكامن في تكوين تريبيل لكن جميعها حفرت بآبار ووجدت جافة. بناء عليه، فإن الخطورة في اعتبار تكوين تريبيل كهدف للتنقيب عن البترول هو انخفاض النفاذية وعدم وجود مكامن جيدة غير محفورة.

الطريقة الوحيدة التي يمكن أن تتسبب في تعبئة المكامن الموجودة في منطقة الدراسة هي من صخور مصدرية داخل منخفض السرحان في الأراضي السعودية. بما أن المنخفض كان يشكل بيئة أعمق خلال معظم حقبة الحياة القديمة، فإن الظروف مواتية لتكون صخور مصدر داخل المنخفض. هذا يعني أن النفط يمكن أن يكون قد نشأ داخل منخفض السرحان ثم هاجر من خلال الحدود الأردنية ووصل إلى مكامن السرحان في الأردن وقام بتعبئتها لأنها موجودة على ارتفاعات أعلى من المنخفض. لكن المحظور الوحيد في هذه الهجرة هو أن النفط سيمر أثناء هجرته على الكثير من الصدوع النامية التي تعد مخارج تسمح بهروب النفط. وعليه، فإن التنقيب عن البترول في منطقة السرحان جنوب شرق لأردن هو مجازفة كبرى.

الكلمات الدالة: حوض السرحان، البترول، مصيدة، مكمن، صخر مصدر، صخر كتيم.

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