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# Evaluation of the Lower Devonian Tadrart Reservoir in X Oilfield, Ghadames Basin, Libya

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**Keywords:**
Reservoir rock
Core descriptions
Petrophysical analysis
Porosity
Pay thickness
Water saturation

**A B S T R A C T**

The Ghadames Basin situated in northwestern Libya and extending into Algeria and Tunisia contains up to 6,000 square kilometers of Paleozoic and Mesozoic. Reservoir evaluation is of great importance in the oil and gas industry, as it helps understand the characteristics of the reservoir and predict the behavior of the reservoir over time The focus of this study deals with the sedimentology analysis and reservoir evaluation of Lower Devonian Tadrart Sandstone, Petrel software. Techlog software and detailed core analyses were integral tools used for the study. The findings reveal that Tadrart-D1 locally subdivided into sub zone Tadrart-D1a.Tadrart-D1aSH and Tadrart-D1b, Tadrart-D1b represent the main reservoir composed of estuarine, tidal sand flats and shore face deposits. The Tadrart Reservoir exhibits favorable qualities. A thickness map generated using significant variability in the gross formation thickness, ranging from 133 to 310 feet. Petrophysical analysis estimates the net pay thickness of the Tadrart-D1b unit between a few feet and 60 feet, with porosity reaching up to 16%, water saturation peaking at 49%, and shale volume measuring up to 16%. For the Tadrart-D2 unit, the maximum thickness reaches 45.5 feet, with porosity varying between 7% and 17%, water saturation between 35% and 56%, and similar depositional characteristics. Core descriptions compared with log signatures and petrophysical results allowed for the accurate identification of depositional environments associated with these units.

# تقييم خزان تادرارت الديفوني السفلي في حقل النفط X، حوض غدامس، ليبيا

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**الكلمات المفتاحية:**
صخور المكمن
وصف عينات اللب
التحليل البتروفيزيائي
المسامية
سمك الطبقة الصخرية
تشبع الماء

**الملخص**

يقع حوض غدامس في شمال غرب ليبيا ويمتد إلى الجزائر وتونس ويحتوي على ما يصل إلى 6000 كيلومتر مربع من حقبتي الحياة القديمة والوسطى. إن تقييم الخزان له أهمية كبيرة في صناعة النفط والغاز، لأنه يساعد على فهم خصائص الخزان والتنبؤ بسلوك الخزان بمرور الوقت. يركز هذا البحث على تحليل الرواسب وتقييم الخزان لحجر رمل تادرارت الديفوني السفلي، وبرنامج بيتريل. كذلك برنامج تيك لوج وتحليلات اللب التفصيلية أدوات متكاملة استخدمت في الدراسة. تكشف النتائج أن تادرارت-D1 مقسم محليًا إلى نطاقات فرعية تادرارت-D1a.Tadrart-D1aSH وتادرات-D1b، وتادرات-D1b تمثل الخزان الرئيسي المكون من رواسب مصبات الأنهار والمسطحات الرملية المدية ورواسب واجهة الشاطئ. يظهر خزان تادرارت صفات مواتية. خريطة سمك تم إنشاؤها باستخدام تباين كبير في سمك التكوين الإجمالي، تتراوح من 133 إلى 310 قدمًا. يُقدّر التحليل البتروفيزيائي سمك الطبقة الصخرية الصافية لوحدة تادرارت-D1b بين بضعة أقدام و60 قدمًا، مع مسامية تصل إلى 16%، وتشبع مائي يصل إلى ذروته عند 49%، وحجم صخر طينيّ يصل إلى 16%. أما بالنسبة لوحدة تادرارت-D2، فيصل أقصى سمك لها إلى 45.5 قدمًا، مع مسامية تتراوح بين 7% و17%، وتشبع مائي يتراوح بين 35% و56%، وخصائص ترسيبية متشابهة. وقد أتاحت مقارنة أوصاف العينات اللب ببصمات السجلات والنتائج البتروفيزيائية تحديدًا دقيقًا للبيئات الترسيبية المرتبطة بهذه الوحدات.

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## 1. Introduction

Libya has five major sedimentary basins, located in onshore and offshore which are Sirte, Murzuq, Kufra, Ghadames and Sabratah Basin. The Location Ghadames Basin at longitude (10°30 to 14°00 E) and latitude (28°30 to 31°30 N) (Figure. 1). The Caledonian Orogeny influences it during the Cambrian to Lower Devonian, which resulted in the emergence of the Gargaf Arc over the basin. The northern part of the basin was uplifted during the Hercynian folding (Lower Devonian to Lower Triassic), [1].

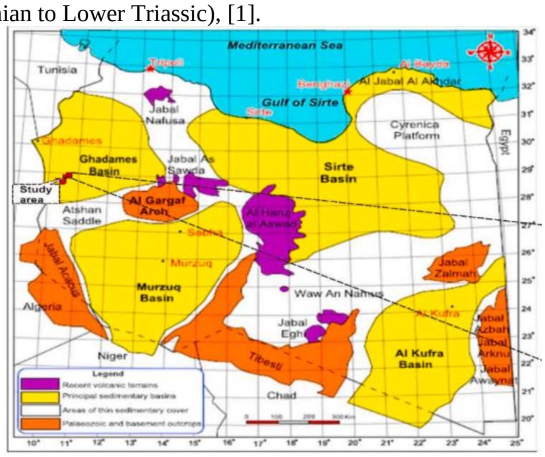


**Fig.1:** location map of Ghadames Basin [2]

Most of the hydrocarbon accumulations controlled by the distribution of the Silurian and Devonian sedimentary successions, which host the main hydrocarbon source and reservoir [3], the main reservoir of interest in Ghadames Basin is Lower Devonian Tadrart Sandstones. [3], Tadrart Formation has been penetrate in many wells where it is represent by thick bedded, massive sandstone, white to light grey, generally fine to coarse grained with rare thin beds of shale[4]. The reservoir evaluation process is subject to numerous challenges. These include reservoir complexity, changes in reservoir control over time, environmental challenges, and the need for accurate data. The importance of studying oil reservoir evaluation lies in determining the size of available oil resources and the possibility of obtaining them in full. This helps inform decision-making and contributes to the development of oil reserves and their investments. These studies also contribute to improving the utilization of oil, by analyzing the geological and physical characteristics of the reservoir, it is possible to determine how easy or difficult it is to extract oil and gas, and thus determine the best techniques and methods for extraction operations. The link between initial depositional attributes and evolution of the pore system are elemental for petroleum exploration [5], [6]. Petrophysics employed to help reservoir engineers and geologists understand the properties of reservoir rocks, particularly how pores in the subsurface interconnect and control the accumulation and migration of hydrocarbons. The most important properties studied in petrophysics are lithology, porosity, water saturation and permeability,

### 1.1General stratigraphy of the Ghadames Basin.

The stratigraphic sequence has a maximum thickness in the range of 15000 to 17000 feet at the depocenter; the basin consists of two major sedimentary cycles, the Paleozoic and Mesozoic, divided by a major angular unconformity of Hercynsian age [7]. During the Late Silurian and Lower Devonian, several transgression/regression cycles caused continental deposition over much of the area, which followed by marine deposition through to Carboniferous times. Sea level changes produced the major reservoirs of the Ghadames Basin in the Upper Silurian (Acacus Formation) and Lower Devonian Tadrart Formation, (Figure 2). Continental sand accumulated in the Triassic while in the Jurassic and Cretaceous accumulation of lagoon dolomites, evaporates and shales was dominant. Devonian succession are expose along the edges of the Ghadames Basin, in the central part of the basin, an almost complete series of Devonian rocks can be found Lower, Middle, and Upper Devonian [8]. The Lower Devonian layers of the Tadrart sandstone vary in thickness (about 400 m) and include continental and marine silicate rocks [9] .The typical section of the Tadrart Formation is a prominent slope, eroded by weathering to form large isolated columns of massive, continental-to-marine, ferruginous, cross-bedded sandstones, with plant remains at the bottom and traces of fossils at the top.

### 1.2 The Objective

The main objective of the study is Investigate the Reservoir rock quality (lower Devonian) Tadrart reservoir within X oil field and their Distribution in study area by selected five exploration wells.

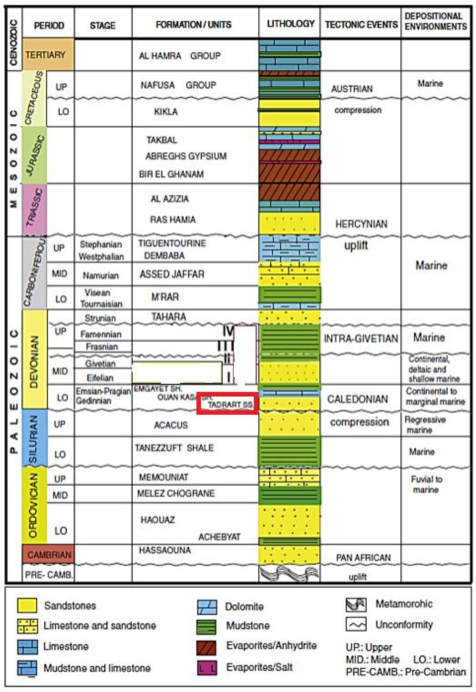


**Fig.2** Tectonic -Stratigraphic chart of Ghadames basin [9]

### 1.3 Location of the study area.

The X Oil Field located in southern flank of the Ghadames Basin midway between Al Garaqaf uplift to the south, and the center of the basin, the located on Longitude (26° 20 '06 N ) and Latitude (16° 05 '58 E) . Shown Figure. 3

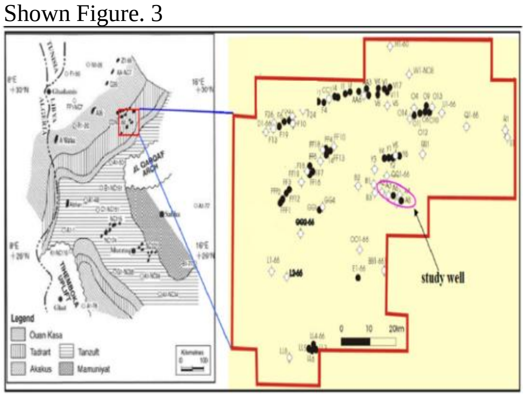


**Fig.3** Location map shows study area,

## 2. Data Methodology

The study based on available subsurface data for five exploration wells drilled in the study area (A 2, A 5, A 6, A 7and A 11), wells distributed in X Oilfield. Two method used the direct method core analysis (Conventional Core analysis Porosity,-permeability-and fluid saturation analyses and core description. Indirect method wire line logs (GR, Resistivity, Sonic, Density and Neutron). Calculating the volume of shale, effective porosity, water saturation, net pay, net to gross ratio and geological software (Petrel Software using geological data generation of thickness map. Techlog Software Techlog platform one of the best software uses for determining the petrophysical properties), shown (Figure 4)

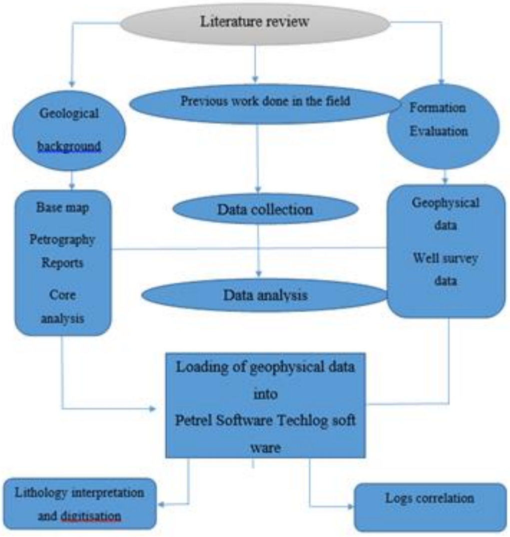


**Fig.4** flowchart outlining the entire methodological.

### 3. Results and Discussion

### 3.1 Core description.

The sedimentary depositional environments can be broadly categorize into continental, transitional, and marine settings. Continental environments include those on land, like rivers, lakes, and deserts. Transitional environments are at the boundaries between land and sea, such as deltas and estuaries. Marine environments are associated with oceans and seas, including shallow and deep-water settings. Core sampling description is of great importance in oil and gas wells. It is allows us to identify and determine the rock type, depositional environment and facies, in this study core samples from the well A2, A3, A5 and A6 described. Tadrart Formation in X oil field divided into eleven facies associations based on the lithologies, sequences and sedimentary structures (Table 1). .

**Table (1)** Summary of facies associations

| Broad Environment | Environment | Facies | Code |
|---|---|---|---|
| Offshore, subtidal | Shelf sea | Monotonous mudstones, fissile, locally burrowed | SS |
| Nearshore, subtidal | Lower shoreface | Heavily bioturbated, argillaceous, very fine sandstones, | LSF |
| Nearshore, subtidal | Middle-upper shoreface | Clean, well sorted, mainly fine grained sandstones showing planar lamination and low angle cross bedding. Locally massive. | USF |
| Nearshore, subtidal | "Distal" lagoon, inner shelf | Mainly mudstone, sand lenses, laminae, burrows. Local cracks and wave ripples. No evidence for subaerial exposure | DL |
| Nearshore, subtidal | "Proximal" lagoon, inner shelf | Interbedded SST and mdst. Sst cross bedded, with mud drapes, mud clasts, current ripples, locally bioturbated, Mdst laminated. | PL |
| Intertidal and subtidal | Estuarine channel | Cross-bedded sandstones with mud drapes, mudstone clasts, and local bipolar cross bedding, slumping and burrows | EC |
| Intertidal | Tidal creek | Interbedded sandstones and mudstones, cross-bedded SST, mud drapes, mud clasts, slumping, evidence for subaerial exposure such as desiccation cracks and rootlets | TC |
| Intertidal | Tidal sand flat | Fine & very fine sandstones containing common wavy arg lam, mud clasts, current & wave ripples, local burrows & mud cracks. | TSF |
| Intertidal | Tidal mud flat | | TMF |
| Coastal plain/supratidal | Fluvial channel | Cross bedded sand stone lacking mud | FC |
| Coastal plain/supratidal | Floodplain | Mudstones and arg SST. Thin clean cross bedded sst (crevasse splays, channel abandonment) | FP |

**WELL A5 Core 1: (4,120 - 4,121 ft.)**

Only three feet of core have been recovered from core #1 (Tadrart-D1), consisting of clean, medium grained sandstone overlain by a medium-dark grey mudstone. Given the limited core, length there is little sedimentology evidence for interpretation. However, the presence of faint cross-lamination in the sandstone together with minor burrowing suggests that the sandstone may represent either a marginal marine channel sand body or possibly part of a lower shore face, Table (1)

**WELL A5; Core 2: (4,094. - 4,099 ft) well A5**

The base of core #2 (Tadrart-D1) comprises of highly argillaceous sandstones, represented by bioturbated and deformed heterolithic beds. The sandstones are fine-grained with numerous burrows, including paleophycus, (Figure 5), and rare preserved, draped-ripple lamination. Thin lag deposits interbedded with the sandstone, with pebbles and clasts up to 15 mm diameter, the trace fossils suggest a tidal flat environment of deposition. The presence of thin conglomeratic layers is interpret as transgressive lag deposits preceding deposition of a thick marine mudstone (Emgayat Formation). Common siderite and reddening (oxidized siderite and pyrite) could be evidence for condensed sedimentation. Figure 6-show core description summary for well A5.

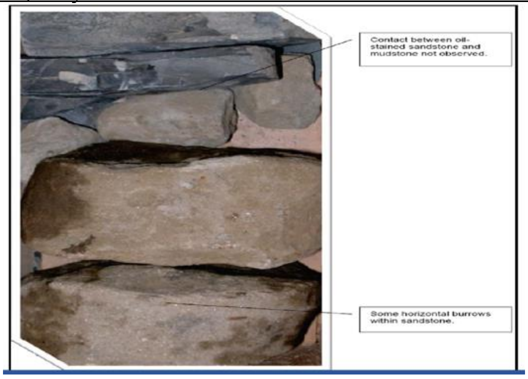


**Fig 5:** Marginal marine sandstone, 4,120.4 - 4,121 ft, well A5

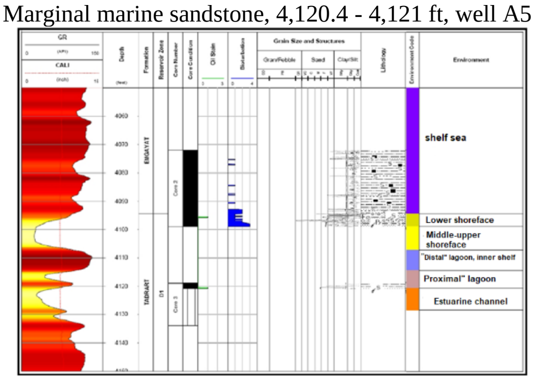


**Fig6:** Core description summary for well A5

**Well A6-; Core #1: 4,065 - 4,095 ft.**

The first three feet of core 1 is composed of Sandstone (Tadrart-D1) with common mudstone clasts, fine grained, generally massive, with possible load structures locally. The lower part of core 1 is mainly composed of a 12 ft. thick Sandstone; pale to dark yellowish brown (oil stained), friable, porous, locally argillaceous, with mudstone clasts, medium to very coarse grained, vaguely to clearly cross bedded, with argillaceous laminae and local mud drapes on foresets. Mudstone clasts are locally sideritic and light brown (Figure 6).

**Core #2: 4,095 - 4,115 ft.**

The top of the core #2 interval in well A6 comprises of a 5 ft. thick interval pale to dark yellowish brown (oil stained) sandstone (Tadrart-D1), friable, porous, locally argillaceous, with mudstone clasts, medium to very coarse grained, vaguely to clearly cross bedded, with argillaceous laminae and local mud drapes on foresets. Mudstone clasts are locally sideritic and light brown. With common wavy argillaceous laminae, current and wave rippled, locally cross-bedded, locally with load structures, with possible cracks, with simple, inclined burrows. These Sandstones interbedded with Mudstone, possibly part of tidal flat deposit, Table (1) (Figure 7).

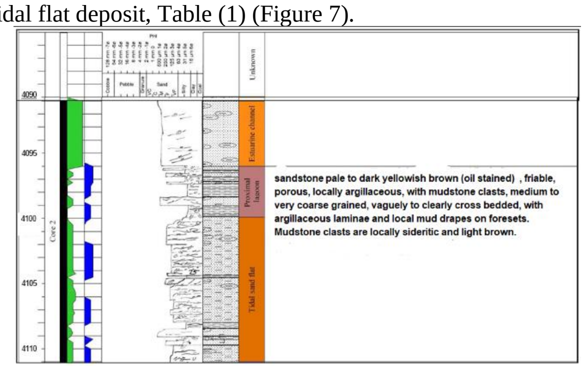


**Fig 7:** Core #2 description of Tadrart-D1 sandstone in well A6

### 3.2 Stratigraphy and Sedimentology.

Tadrart Formation locally subdivided in the study area into three sand-dominated intervals from Tadrart-D1 (youngest) to Tadrart-D3 (oldest). Reservoir zones Tadrart-D1 and Tadrart-D2 separated by an apparently correlate able mudstone-dominated D1SH interval. Notably, most Tadrart cores from this study are from the uppermost Tadrart-D1 interval, Tadrart-D1 divided into 3 sub-zones as follows (Table 2)

- Tadrart-D1a (dominantly sandy)
- Tadrart D1aSH (Shale)
- Tadrart-D1b (dominantly sandy)

**Table 2:** Summary of the correlation scheme followed for the Tadrart reservoirs.

| Pick Name | Description |
|---|---|
| Top Emgayat | Shale with thin sands beds |
| Top Tadrart-D1 | First sandstone after Emgayat, with some shale interbeds |
| Top Tadrart-D1aSH | First shale layer below Emgayat |
| Top Tadrart-D1b | Second thick sandstones below Emgayat |
| Top Tadrart-D1SH | Second thick correlateable shale below Tadrart D1 |
| Top Tadrart-D2 | Cleaner sandstones with some shale interbeds below the D1SH |
| Basal Shale | Thick shale sequence after D2 sandstones |

**TADRART D1a SH**

The TADRART D1aSH it is first shale layer below Emgayet formation showing the difference in the distribution of thickness in the study area the thickness reached about 12 ft in well A6 While the thickness reached about 6 ft in well A2 in west.

**TADRAT- D1**

The Tadrart-D1 horizon. This interval has been interpret as a series of estuarine/tidal channel sandstones that cut through the marginal marine environment (sand flat, mudflat, tidal creek, and lagoon/bay). They are inter bedded with some relatively thick mudstone intervals that have been interpreted from core in wells A3- as inshore or distal lagoon These sandstones may reach 66 ft thick and represent amalgamated deposits from relatively shallow estuarine/tidal channels. The log response for these intervals shows low gamma, Figure 8 shown Tadrart-D1.

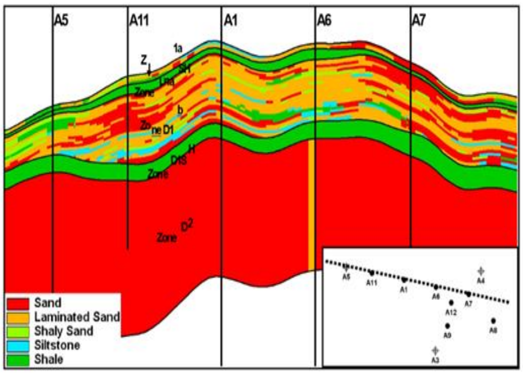


**Fig 8:** Tadrart-D1 is mainly composed of Sand and Laminated Sand, (A11, A1, A6, A7).

**TADRART- D1b**

Tadrart-D1b is the main reservoir and based on the core studies the best reservoir potential in sandstones deposited in the estuarine, tidal creeks and shore face facies. We showing the difference in the distribution of thickness in the study area the thickness ranges about 80 ft in the well ( A6), While the Thickness ranges about 37.5 ft in well (A2) in west , Thickness increases towards the east. Showing figure (7)

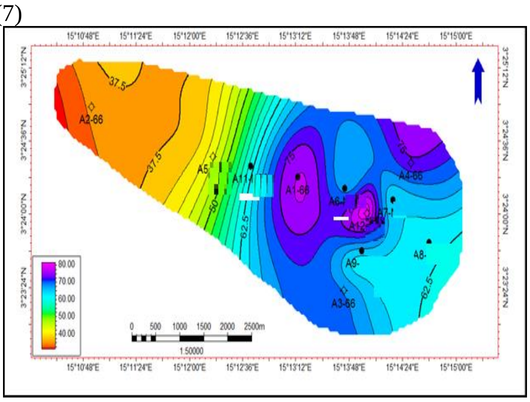


**Fig 9**: Isopach map of TADRAT D1b

**TADRAT – D1SH**

The D1SH is an apparently regionally correlatable shale-rich interval that has been pick in all study wells. However, the interval displays considerable variation both in thickness, the D1SH thins from >66ft to 7 ft, It may be represent by a high gamma log response. (Table 1)

**TADRART – D2**

Tadrart-D2 sand have been describe from a northern well A3 and from an eastern well A6. The D2 in the northern area consists of a fluvial-dominated system, with stacked channel sandstones inter bedded with floodplain crevasse and pale sol deposits. The channel sandstones may be clean and stacked into intervals locally exceeding 66 ft and these are represent by a blocky gamma log response (Figure 8). However more serrate log profiles are also observe, where the channel sand bodies are interbedded with relatively minor floodplain deposits. In our study area,

**3.3. Reservoir quality and layout petrophysical properties**

A complete package of porosity including neutron, density , resistivity logs and gamma ray, have been recorded across the TADRART sandstone reservoirs within study area.

**3.3.1 Net pay thickness:**

The Determination of Property cut-offs for Net pay estimates

There have been many different approaches to quantify cutoffs, with no single method emerging as definitive basis for delineating net pay. Yet each of these approaches yields a different reservoir model, so it is imperative that cutoff be fit for purpose. This study employs the traditional approach alongside [10], Statistical analysis for the core porosity and permeability relationship was performed and unbiased standard deviation of the best fit was used to estimate the lower and upper limits of the porosity cutoffs, which is about 1 porosity unit (Figure 10 and Table 3). Example of net pay generated using optimistic, base case and pessimistic cutoffs shown in Figure 10.

**Table (3)** final cutoffs for Tadrart reservoir

| formation | case | porosity | V cl | Sw | K md |
|---|---|---|---|---|---|
| Tadrart | optimistic | > 6% | < 40% | < 65% | 1 |
| | Base case | > 7% | < 35% | < 60% | |
| | pessimistic | > 8% | < 30% | < 65% | |

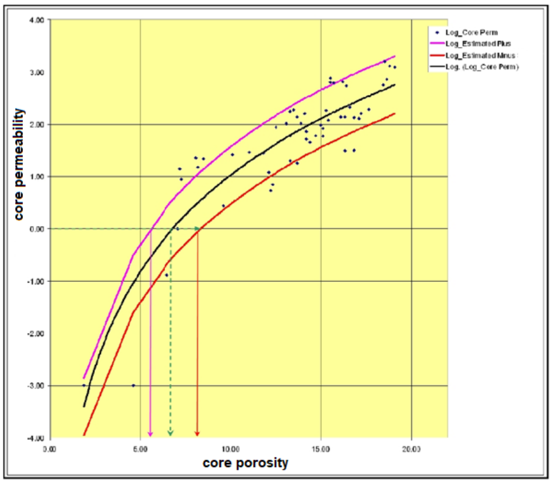


**Fig: 10** Results of the statistical analysis to find the upper and lower limits of porosity cutoffs for net pay estimations for Tadrart reservoir

**3.3.2 Lithostratigraphy of the Tadrart reservoir.**

The first goal of well log investigation is to attempt to identify the lithology down hole and its depth of occurrence, define various characteristics and to integrate them with core data. The lithology in the Tadrart reservoir identified using Techlog software, GR and neutron density cross-plot method. These cross-plots show Tadrart reservoir consists mainly of sand with filaments of shale. Showing (Figure 8, Figure 9),

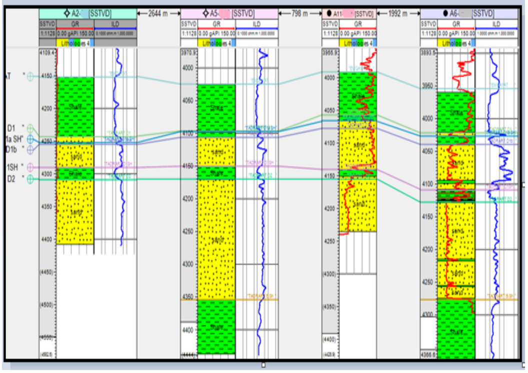

**Fig 11** cross section (A-A'), well (A 2, A 5, A 11 and A 6)

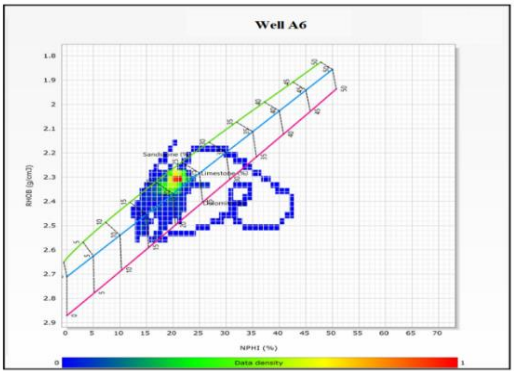


**Fig 12**: cross plot chart of Porosity and Lithology determination from density logs and compensated neutron logs from well A 6

The thickness of the lower Devonian formations (Tadrart) in study well showing in Table 4, (Figure 8)

**Table 4.** The top, bottom and thickness (ft) of the Tadrart formations

| Well | Top (Ft) | Bottom(Ft) | Thickness(Ft) |
|---|---|---|---|
| A2 | 4185 | 4400 | 215 |
| A5 | 4055 | 4350 | 295 |
| A6 | 3980 | 4290 | 310 |
| A7 | 4010 | 4310 | 300 |
| A11 | 4010 | 4143 | 133 |

### 3.4.1 WELL A6:

The formation sandstone with interbred shale, identified by wire line logs, Gamma Ray, shown in (Figure 11) .The interval from 4021. to 4039 feet represent the Tadrart D1 consist sandstone with net pay thickness of 2.075 feet, an average effective porosity 0.116 %, average calculated Water Saturation its 0.465 %, and volume of shale 0.141 %, the interval from depth 4039 to 4108 feet represent the TADRART D1b zone, consist sandstone with net pay thickness of 41.350 average of effective porosity 0.182 %. average calculated Water Saturation its 0.290 % and volume of shale 0.014, indicate an excellent oil-bearing reservoir dominated by clean sandstone, the interval from depth 4128 to 4276 feet represent the TADRART D2 consist sandstone with net pay thickness 23.149 of the average of effective porosity 0.186 %. (Figure 13), Average calculated Water Saturation its 0.564 % and volume of shale 0.192 (Table 5), (Table 6)

**Table (5)** the Results of petrophysical analysis (Well A6)

| Well | A6- | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Zones | TADRART D1 | | | TADRART D1 b | | | TADRART D2 | | |
| Flag Name | ROCK | RES | PAY | ROCK | RES | PAY | ROCK | RES | PAY |
| Top | 4021.520 | 4021.520 | 4021.520 | 4039.540 | 4039.540 | 4039.540 | 4128.040 | 4128.040 | 4128.040 |
| Bottom | 4039.540 | 4039.540 | 4039.540 | 4108.510 | 4108.510 | 4108.510 | 4276.520 | 4276.520 | 4276.520 |
| Gross | 18.020 | 18.020 | 18.020 | 68.970 | 68.970 | 68.970 | 148.480 | 148.480 | 148.480 |
| Net | 4.905 | 3.825 | 2.075 | 63.000 | 55.075 | 41.350 | 122.759 | 122.759 | 23.149 |
| Net to Gross | 0.272 | 0.212 | 0.115 | 0.913 | 0.799 | 0.600 | 0.827 | 0.827 | 0.156 |
| Av_Shale Volume | 0.211 | 0.180 | 0.141 | 0.050 | 0.051 | 0.014 | 0.237 | 0.237 | 0.192 |
| Av_Effective Porosity | 0.169 | 0.121 | 0.116 | 0.174 | 0.169 | 0.182 | 0.165 | 0.165 | 0.186 |
| Av_Water Saturation | 0.555 | 0.642 | 0.465 | 0.364 | 0.382 | 0.290 | 0.677 | 0.677 | 0.564 |

**Table (6)** Results pay zone of petrophysical analysis

| | Top (ft) | bottom | Gross | Net | N/G | AV VSH | AV PHI | AV SW |
|---|---|---|---|---|---|---|---|---|
| (Well A2) | | | | | | | | |
| T D1 | 4243 | 4252 | 12.20 | 1.55 | 0,129 | 0.259 | 0.113 | 0.377 |
| T D1b | 4255 | 4290 | 35.5 | 22 | 0.619 | 0.026. | 0.121 | 0.392 |
| TD2 | 4308 | 4399 | 90 | 6.875 | 0.076 | 0.148 | 0.079 | 0.359 |
| (Well A5) | | | | | | | | |
| T D1 | 4096 | 4104 | 8 | 2.65 | 0.331 | 0.291 | 0126 | 0.398 |
| T D1b | 4106 | 4150 | 44 | 18.5 | 0.420 | 0.017 | 0.164 | 0.521 |
| TD2 | 4170 | 4353 | 183 | 21.5 | 0.117 | 0.140 | 0.172 | 0.342 |
| (Well A6) | | | | | | | | |
| T D1 | 4021 | 4039 | 18.20 | 2.075 | 0.115 | 0.141 | 0.116 | 0.465 |
| T D1b | 4039 | 4108 | 68.97 | 41.35 | 0.600 | 0.014 | 0.182 | 0.290 |
| TD2 | 4128 | 4276 | 148.4 | 23.14 | 0.156 | 0.192 | 0.186 | 0.564 |
| (Well A7) | | | | | | | | |
| T D1 | 4042 | 4056 | 13 | 0.800 | 0.061 | 0.093 | 0.16 | 0.391 |
| T D1b | 4056 | 4121 | 65 | 49 | 0.75 | 0.062 | 0.17 | 0.352 |
| TD2 | 4147 | 4291 | 143 | 6.77 | 0.04 | 0.06 | 0.18 | 0.56 |
| (Well A11) | | | | | | | | |
| T D1 | 4135 | 4150 | 15 | 1.525 | 0.102 | 0.324 | 0.102 | 0.504 |
| T D1b | 4150 | 4228 | 78 | 29.25 | 0.375 | 0.061 | 0.154 | 0.209 |
| TD2 | 4257 | 4399 | 142 | 3.925 | 0.028 | 0.291 | 0.134 | 0.337 |

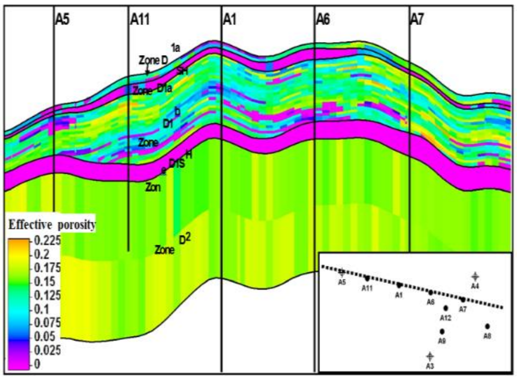


**Fig 13**: Porosity model cross section, showing vertical and lateral porosity distribution in Tadrart in study well

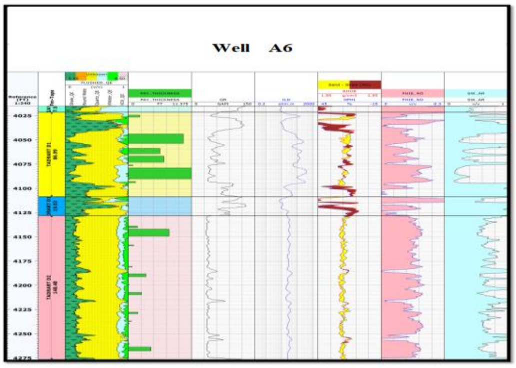


**Fig 14** Petrophysical Evaluation of Tadrart reservoir, well A6

### 3.4.2.2. WELL A7:

The formation sandstone with interbred shale , identified by wire line logs, (Gamma Ray), shown in Figure 15, the interval from 4042 to 4056 feet represent the Tadrart D1 consist sandstone with net pay thickness of 0.800 feet, an average effective porosity 0.165 %, average calculated Water Saturation its 0.397 %, and volume of shale 0.0.093 %. The interval from depth 4056 to 4121 feet represent the TADRART D1b zone, consist sandstone with net pay thickness of 49.401 average of effective porosity 0.171 %. average calculated Water Saturation its 0.352 % and volume of shale 0.051, indicate an excellent oil-bearing reservoir dominated by clean sandstone, the interval from depth 4147 to 4291 feet represent the TADRART D2 consist sandstone with net pay thickness 6.775 of the average of effective porosity 0.185 %, average calculated Water Saturation its 0.567 % and volume of shale 0.062 . Showing Table 6, Table 7

**Table (7)** the Results of petrophysical analysis, (Well A7)

| Well | A7 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Zones | TADRART D1 | | | TADRART D1 b | | | TADRART D2 | | |
| Flag Name | ROCK | RES | PAY | ROCK | RES | PAY | ROCK | RES | PAY |
| Top | 4042 | 4042 | 4042 | 4056 | 4056 | 4056 | 4147 | 4147 | 4147 |
| Bottom | 4056 | 4056 | 4056 | 4121 | 4121 | 4121 | 4291 | 4291 | 4291 |
| Gross | 13.060 | 13.060 | 13.060 | 65.510 | 65.510 | 65.510 | 143.490 | 143.490 | 143.490 |
| Net | 4.160 | 1.375 | 0.800 | 65.225 | 58.900 | 49.401 | 100.726 | 99.326 | 6.775 |
| Net to Gross | 0.319 | 0.105 | 0.061 | 0.996 | 0.899 | 0.754 | 0.702 | 0.692 | 0.047 |
| Av_Shale Volume | 0.141 | 0.137 | 0.093 | 0.011 | 0.012 | 0.051 | 0.189 | 0.191 | 0.062 |
| Av_Effective Porosity | 0.194 | 0.134 | 0.165 | 0.171 | 0.164 | 0.171 | 0.149 | 0.148 | 0.185 |
| Av_Water Saturation | 0.348 | 0.513 | 0.397 | 0.387 | 0.400 | 0.352 | 0.737 | 0.742 | 0.567 |

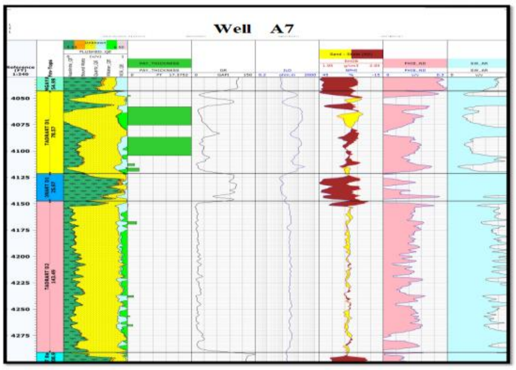


**Fig 15:** Petrophysical Evaluation of Tadrart reservoir, well A7

3. Conventional Core analysis

Seventy-nine cylinder plugs sample collected from well A6, Sixty-five from D1b, and fourteen sample from D2 for conventional core analysis (CCA), and laboratory measurements of porosity, grain density, and permeability performed at the Libyan Petroleum Laboratory. The result Tadrart-D1b were minimum porosity 8.1 %, and maximum porosity for 19 %, it was average porosity 17.6%. Minimum permeability 23 md, and maximum permeability 200 md, it was average permeability 186 md. Minimum Grain density 2.617 g/cm3, and maximum Grain density 2.647 g/cm3, it was average Grain density 2.635 g/cm3. Showing Table 8

**Table (8)** the Results of conventional core analysis, (Well A6)

| properties | D1b | | | D2 | | |
|---|---|---|---|---|---|---|
| | Number of plug ( 65) | | | Number of plug ( 14) | | |
| | Min | Max | Av. | Min | Max | Av. |
| permeability K (md) | 23 | 200 | 186 | 18 | 158 | 145 |
| porosity % | 8.1 | 19.2 | 17.6 | 4.5 | 13.6 | 11.8 |
| Grain density | 2.617 | 2.647 | 2.635 | 2.513 | 2.65 | 2.623 |

**4. Conclusion and Recommendations.**

**4.1 Conclusion**

All available data (well logging data and some core sample), was integrated to Identification of the lithofacies types , depositional environments of lower Devonian deposits and evaluate the lithology, saturation, porosity, permeability volume of shale of the in 5 wells (A2, A3, A6, A7 and A11).

1- Sedimentology study of The Tadrart Formation in X oil field divided into eleven facies associations based on the lithology, sequences and sedimentary structures

2-- Tadrart Formation locally divided in Tadrart-D1, D2 and D3. Tadrart-D1 subdivided into sub zone Tadrart-D1a.Tadrart-D1aSH and Tadrart-D1b, theTadrart-D1b consist sandstone represent the main reservoir composed of estuarine, tidal sand flats and shore face deposits, the depositional environments identified through core descriptions, compared with the log signatures and petrophysical analysis.

3- Isopach map for, Tadrart-D1b, were generated based on the horizon correlation to understand the sand distribution show variable gross thickness of Tadrart formation ranging from 37.5 to 80 feet, Thickness increases towards the east .

4- Petrophysical analysis identified Tadrart D1 consist sandstone with net pay thickness 2.07 feet, average effective porosity 0.11 %, average calculated Water Saturation its 0.46 %, volume of shale 0.141 %, the net pay thickness of the Tadrart-D1b ranging from view feet to 47 feet, porosity reached up to 16%, water saturation reached up to 49% and the volume of shale reached 16%. The Tadrart-D2 with maximum thickness of 45.5 feet, the porosity ranging from (7- to 17%), water saturation ranging from (35 to 56) and Volume of shale reached 14%.

5- Conventional Core analysis for Tadrart-D1b were minimum porosity 8.1 %, and maximum porosity for 19 %, it was average porosity 17.6%. Minimum permeability 23 md, and maximum permeability 200 md, it was average permeability 186 md. Minimum Grain density 2.617 g/cm3, and maximum Grain density 2.647 g/cm3, it was average Grain density 2.635 g/cm3.

**4.2 Recommendations**

We recommend further sedimentary studies to gain more information on the depositional environment, as well as further 3D seismic surveys to define the structure configuration.

**Acknowlegment**

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