

Reservoir Characteristics and Facies Analysis of the Lower Member of the Silurian Acacus Sandstones, Concession NC2, Ghadames Basin, Northwest Libya

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Summary

The petrophysical characteristics of a sedimentary unit are changeable with time. Since the permeability value in this area of the study is more than 0.01md, the irreducible water won't exceed with time (Byrnes 1996 Reservoir Characteristics). The low permeability, which is 3md in the Lower Acacus reservoir has undergone three diagenetic facies (quartz-cemented facies, carbonate-cemented facies, and clay-cemented facies). Furthermore, with permeability 3md and porosity values around 15%, the secondary porosity is probably well connected and contributing to flow.

Introduction

Ghadames Basin is one of the largest basins in North Africa; it covers some parts of three North African countries which are Algeria, Tunisia, and Libya as shown in figure (1). The lower member of the Acacus sandstones is considered as the main oil target bed in central and southeast Ghadames Basin. In fact, the control keys of the petroleum system in Ghadames Basin are mainly the topographic "relief," and the sedimentary process, which is erosion. The complicated sedimentological features of the Silurian Acacus sandstones present vastly varying petrophysical properties. This study attempts to interpret the petrophysical properties of main reservoir rock in part of concession NC-2 as shown in figure (2). The combination of well data interpretation and thin section observation from the core that obtained from the Arabian Gulf Oil Company, Benghazi-Libya, illustrates identical results concerning the petrophysical characteristics and three sandstone facies of the lower member of the Silurian Acacus sandstone. These facies are quartz-cemented facies, carbonate-cemented facies, and clay-cemented facies. These three different facies represent a change from fluvial sandstone to marine sandstone in the delta system along a southeast-northwest zone of the study area (Petroconsultants, 1996a).

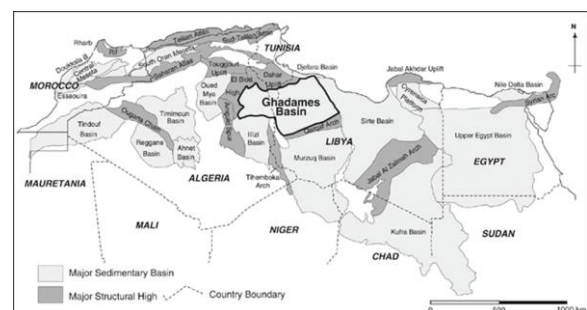
To obtain more accurate results, gathering information from different types of logs such as gamma ray, deep induction resistivity, sonic, density, and neutron logs were necessary for better interpretation. In the Lower member of

Acacus sandstones, the irreducible water won't increase because the amount of permeability is more than 0.01md. In addition, The Bulk-volume-water cross plot (BVW) shows the irreducible water zone where water will be stuck at uninvaded zone by capillary pressure within the irreducible water zone. Therefore, the hydrocarbon product from this area will be free water. Furthermore, the well log data results determine the high oil saturation at 71%, and oil-water contact at depth 9130 ft and 9136 ft. Gamma ray logs show the three facies analysis, which meets the results that obtained from the petrographic study of the thin sections.

One core has been described the lower part of the Lower Acacus Formation showed the varieties of the depositional environment that changed as well E1-NC2 from 9150 ft to 9100 ft; Dis. Delta formation to Prx-Delta formation by the naked eye, as well as the thin sections interpretation.

The stratigraphic correlation of seven wells from the study area represents the lateral change of different depositional environments, which matched the results of the petrographic study that has been done in the same area. Also, significant features have been founded by a petrographic study such as compaction of grains, partially calcite cement, dissolution of partial calcite cement (caused the second porosity), Illite cement as a final stage of diageneses, and dolomitization (dolomite cement fills pores).

Structural part illustrates a series of uplifting in wells (A1-NC2, C1-NC2, E1-NC2, and B1-61) and subsidence in wells (U1-23, T1-23, and B3-61), as well as a period of erosion which noticeable in wells C1-NC2, E1-NC2. Moreover, there is a possibility of vertical migration path along faults from down-dip to up-dip, because the channel is cutting deeper, so that the well B3-61, which located in the down-dip, is dry.



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Figure 1. Location of the Ghadames Basin within the major sedimentary basins and tectonic elements of North Africa (modified from Badalini et al., 2002).

Methods and results

- Cross Plot chart interpretation:

a) Bulk-volume-water cross plot (BVW): this chart was useful to identify the irreducible water area where the hydrocarbon products are predictable to be free water. We market the BVW constant values (0.01) regarding effective porosity, PHIE, vs. water saturation, S_w .

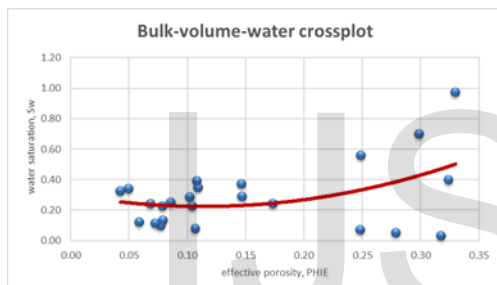


Figure 3. Bulk volume water cross plot (apparent porosity, Phi vs. water saturation, S_w), Lower Acacus sandstones.

b) Pickett cross plot: In order to get the bearing water line where the saturation of water S_w is a hundred percent. We could estimate some important ingredients from this chart, such as R_{i0} , R_w , m, etc.

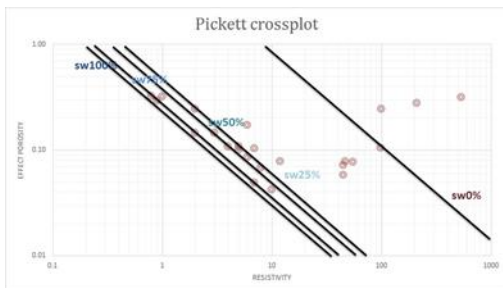


Figure 4. Pickett cross plot of resistivity, I_L , versus porosity from well E1-NC2

- Well logs data:

a) Lithology log: the shale volume was estimated by Gamma Ray Log. Indeed, the first step was estimating the gamma ray index value by using this formula:

$$V_{sh} = 0.33 * (2 * IGR - 1) * 100 \dots \dots \dots (1)$$

b) Porosity logs: to get an accurate effect porosity value, using the combined Sonic and density log and neutron log together, were necessary. We used the next formula to subtract the shale porosity (the nearest porosity to shale zone) volume of the reservoir so that the porosity will refer just to the pay area in the reservoir.

$$\Phi_{eff} = \Phi_{log} - V_{sh} * \Phi_{Sh} \dots \dots \dots (2)$$

c) Resistivity Log: the deep induction log was used in this area to determine water saturation zone regarding the oil water contact OWC. It is certainly clear the matching between the values of the water saturation (S_w) as well as the oil saturation (S_o) with the well logs signature behavior in the figure below at approximately depth 9132ft (OWC).

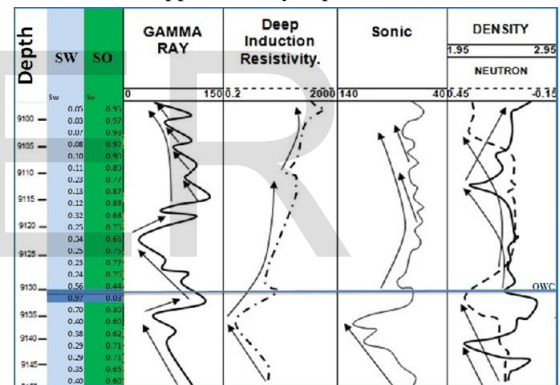


Figure 5. Well data represent W/O contact.

- Combining Core interpretation with Petrographic study: We determine the three different cement facies (they are obviously represented by three parasequences in the figure below) by analyzing ten thin sections of Lower Acacus (A14) unit well: E1-NC2 within the interval 9100 ft to 9150 ft.

Thin Section (T.S) Description	T. S	Gross Lithology	Depth (ft)	Grain size (cl, sil, v, f, m, c, v, y, t, f, s, s, c, s)	Description	Oil Status	Depositional environment
			9100		SST: wh to brn, Qtz, m.grd, sub-rnd & rnd, ind, v.wstr, mud clas, x-lam, silty calc, O st.		Prx-delta. fro
			9105		SLST: gnsh to gry, v.f grd, biot, highly ind, w dk SH lam.		Dis. Delta. fro
			9110		SH: dk x-lam, mic, highly lam, w/v. biot		marine
			9115		SST: gnsh yet, crs grd, v. cpct		Prx-delta. fro
			9120		SITY SH gnsh gry v.h bio, with md clast		Dis. Delta. fro
			9125		SITY SST yet vcrs to crs with v.h bio		Prx-delta. fro
			9130		SITY SH gry v cpct with h. bio		Dis. Delta. fro

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Figure 6. Core and thin sections description from well E1-NC2

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Figure 7c. Regional facies analysis of NC-2, this figure, illustrates the progradation from Southeast – Northwest with an aspect of aggradation in the vertical change of depositional units. In addition, it shows the regional tectonics of Lower Acacus Formation, the series of uplifts and subsidence that caused the series of normal faults. It is obviously clear the lateral change of sediment facies.

- Correlation:

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Integration between, the correlation, cross section, structure cross section, and Gamma Ray lateral facies analysis. By doing this combination, we draw the regional facies map. The regional facies map clearly shows the three different regions of facies as well as the uplifts and subsidence and the three major normal faults.

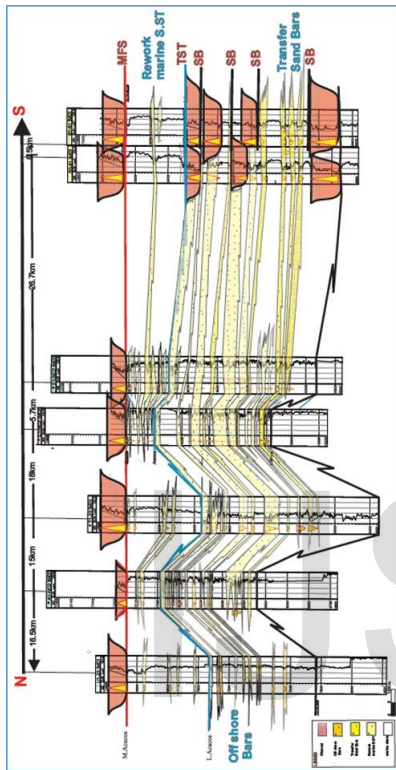


Figure 7a. Stratigraphic correlation between wells (B1-61, B3-61, E1-NC2, C1-NC2, T1-23, A1-NC2, U1-23)

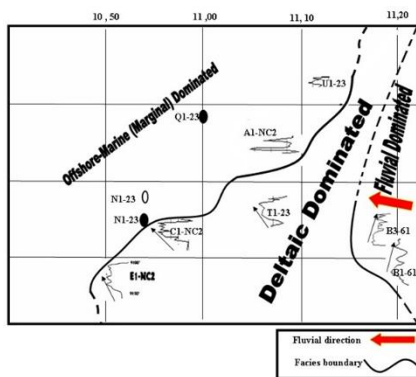
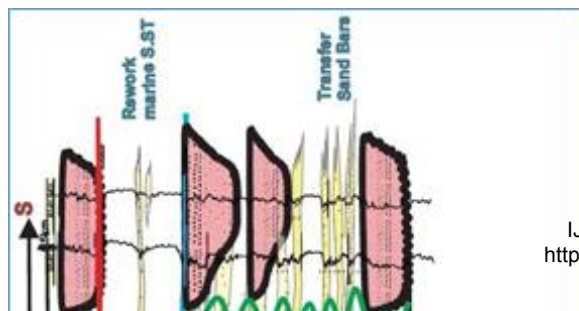


Figure 7b. Lateral Facies analysis as shown by Gamma Ray signature along Southeast – Northwest of the study area.



Conclusion

The Lower Acacus Formation has undergone three diagenetic facies as well as regional tectonic which created the second porosity. The value of permeability which is 3md was not that good; nonetheless, with this value, the irreducible water won't increase because the permeability had to be less than 0.01md to give a possibility of the irreducible water to enlarge. Furthermore, the bulk volume water (BVW) was constant for the most of the Acacus Reservoir so that the hydrocarbon product will be free water for the most of this reservoir. With all of these circumstances, there is certainly a possibility for the second porosity to be connected so that the permeability will enhance for the better reservoir.

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