



# Lower cretaceous petrophysical reservoir evaluation and petroleum prospectivity in the Jeffara basin (S-E TUNISIA)

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Accepted 10 January, 2014

## Abstract

In the Jeffara area, the Upper Jurassic M'rabtine member is constituted by platform carbonates interbedded with sand and shale. The sand levels form a good reservoir with a porosity of 17 % and a permeability of 130 md. The Lower Cretaceous reservoirs are hydrocarbon producer in the northeastern part of the Jeffara basin. Barremian sandstones (Sidi Aïch Fm.) have tested oil in some wells. Cenomanian Zebbag carbonates are hydrocarbon bearing in the Ezzaouia field and tested oil in El Bibane. The latter and also in some adjacent wells tested oil in the Aptian Orbata carbonates. Commonly, the Jeffara Basin has proven / moderate hydrocarbon play. In the central and northwest part of the basin, based on some control points, the area prospectivity is likely to moderate. Outcrop data as well as petrographical studies, tectono-stratigraphic overview and sedimentological investigation were used to exhibit exploration targets for hydrocarbons and form the proven reservoirs of significant oil-fields (e.g. Ezzaouia, El Bibane and Robbana). The Jeffara basin displays variety of siliciclastic and carbonate reservoirs, most likely extending from Ordovician to Cretaceous time. Source rock kitchens, regionally known within the Ordovician, Silurian, Carboniferous, Permian, Jurassic and Cretaceous successions, are locally deeply buried and fully mature in various parts of the basin. Traps are mainly structural; anticlines at Jurassic and Cretaceous level, forming the hydrocarbon pool in the Ezzaouia oil field. The siliciclastic deposits display substantial heterogeneity resulting from depositional environment and may hold basin-ward structural / stratigraphic traps. These lithofacies are showing hydrocarbon potential and could promote the poorly explored zone where locally several objectives within Jurassic and Cretaceous series are penetrated.

**Key words:** Cretaceous, Jeffara Basin, wells tested, prospectivity

## INTRODUCTION

The Jeffara/Jeffara Maritime Basin is located in the onshore and offshore southeastern part of Tunisia, covering from 33 ° to 34 ° and half toward the North; 10 to 12 degrees on the way of the East. The sea side with shallow water depth, around 50 m is well served by infrastructure that exists in the region such as the oil port of the coastal city of Zarzis, also oil and gas pipelines from Southern Tunisia within the city of Gabes (Figure 1).

In present day, Jeffara/ Jerba Basin occupied the on / offshore faulted area, the transition zone between the emergent Saharan Platform and the Mediterranean Sea.

Most of the area belongs to the Mesozoic subsiding Jeffara Area. It is most likely a pull-apart basin, somewhat bounded by the Melab High and Saharan Platform respectively to the West and South – West and it is extending to the Libyan side Eastward. To the North-East it is bounded by the Pelagian Basin. The early Cretaceous series are

well developed in subsurface around the basin border zones, where the thick sandstone and dolomite bodies of the Meloussi, boudinar and Sidi Aïch formations may constitute locally in the Gulf of Gabes promising reservoir targets. The early exploration activities in jaffara basin revealed same discoveries and important shows are Mesozoic strata. Oil and gas quantities have been produced in Ezzaouia field from late Jurassic M'Rabtime paralic sandstones and



Figure 1. On shore and offshore studied area

Cenomanian inner-ramp carbonates. The geology of the Early Cretaceous deposits is organized in southern Tunisia, well exposed along the Chotts and Dahar areas and well developed in subsurface in the Gulf of Gabes and South East offshore Tunisia. Deep hydrocarbon objectives, such as Triassic reservoirs, main hydrocarbon producer in Ghadames basin are still under assessed in Gabes Gulf and Djefara area. Moreover play evaluation exhibits proven and potential petroleum systems, encountered within Jurassic and Lower Cretaceous series and Cenomanian carbonates and are locally ranked, as moderate to high confidence.

The main objectives of this study are to evaluate the Lower cretaceous reservoir and to investigate the geodynamic and depositional environment controls on the petroleum potential of Lower Cretaceous series in the study area are also envisaged.

**Geological setting**

The Jeffara Basin was likelihood the answer of Saharan Platform flexure and the opening of the Neo Tethys Sea (Moncef, 2010; Lazzez et al., 2008; Dridi and Sedjil, 1991). Therefore the area under review was the results of multitudes tectonic phases where the main are cited as follow (Figure 2)

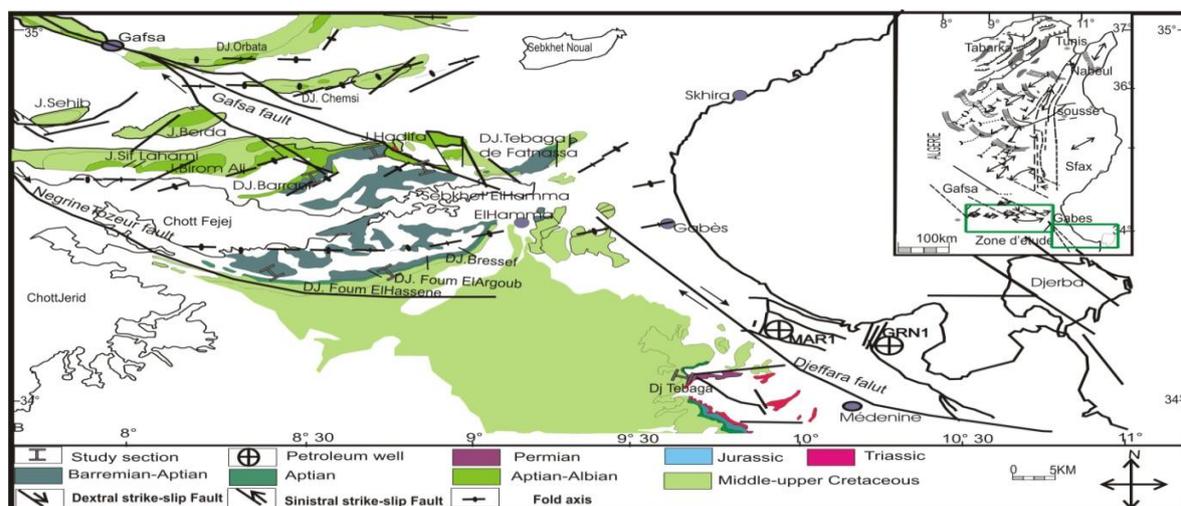


Figure 2. Map of the Chotts trough region and outcropping Lower Cretaceous. Topographic data compiled from the topographic maps listed in the reference section section of this article. Structural data compiled from Abdeljaouad (1985), Ben Ayed (1980), Burollet (1956), Castany (1949, 1950), Castany et al., (1952), Coque (1962), Zargouni et al., (1984), Lazzez et al.,(1985).

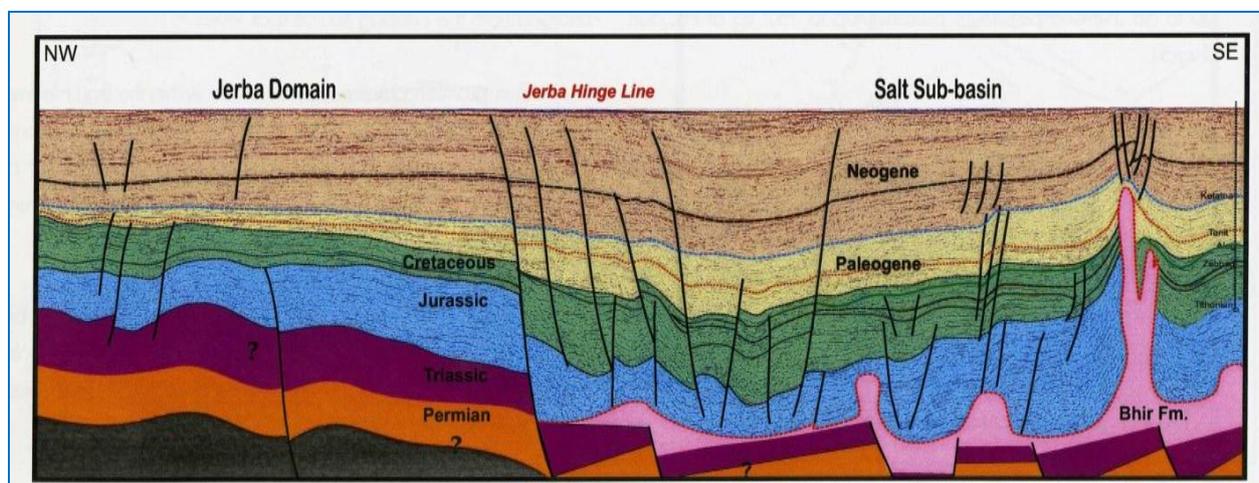
**The Hercynian Orogeny.** It took place during Late Carboniferous – Early Permian. The uplift during Late Carboniferous to Early Permian created visibly, in Southern Tunisia the E-W trending Telemzane – Bou Nemcha Arch where, the Paleozoic formations were eventually eroded.

While this Ghadames basin continued to subside gently, the Jeffara domain in the Northeast where NW - SE major faulted bounded was strongly subsiding and then receiving deposition during Carboniferous, Permian and Lower to Middle Triassic time. This event has influenced steadily the depositional setting of the Middle to Late Triassic and continued throughout the Lower to Middle Jurassic time.

A major tectonic event related to *Austrian Orogeny* occurred during the Late Aptian to Early Albian causing local inversion and therefore intensively affected the area. This event has most likely led to erosion of most of the Senonian series within and surrounding Jerba Island, where in some control points, Oligo-Miocene is overlaying unconformable Cenomanian Zebbag Formation (Lazzez et al., 2008)

### Hydrocarbon traps

As regional structural relief above the unconformity is extremely gentle, these would have become less effective with increasing distance from the sub crop, tending to disperse hydrocarbons widely towards the lower cretaceous reservoir in a wide variety of trapping closures were formed on the studied area at different times. These range from Anticline, Fault-controlled, Stratigraphic, Salt related traps (Truncation) and Sub-salt structures in eastern side mainly to the broad regional domes of Bhir formation in SE during the multitudes tectonic phases, to the very high relief wrench fault structures and very subtle low- relief closures in the Djeffara area (Figure 3).



**Figure 3.** Simplified geo-seismic cross –section showing fault controlled, salt related and possible sub-salt traps. The latter is mainly in south-eastern side (salt sub-basin).

### Subsurface reservoir study

Clastics and Carbonate reservoirs showing excellent fractures and vuggy porosity was described in the fields In the Jeffara Basin. The Late Jurassic Mrabtine Formation is defined as proven reservoirs with high confidence within and surrounding hydrocarbon deposit (EZZ and EBB fields) (Moncef, 2010; Lazzez et al., 2008, Youssef, 2008; Dridi and Sedjil, 1991). Lower Mrabtine member (Late Oxfordian – Early Kimmeridgian): It is predominantly made of intercalation of carbonate and claystone admitting locally sand layers topward. Oil and gas shows with porosity ranging between 13 to 17% were reported from EZZ. This unit is top sealed by intra-formational shale. Middle Mrabtine member (Kimmeridgian): This Upper Jurassic is marked by shelf energy carbonate with local prograding sand layers within and surrounding Zarzis Peninsula. These sand bodies are probably sourced from South. Net pay sand (oil and gas) is 15 m with porosity between 10 and 19%. The Upper Mrabtine shale and evaporate may act as top seal. The lower cretaceous rocks of south-eastern Tunisia consist of sedimentary sequences identified by sea level, lithology and their biostratigraphic content changes. The Barremian Sidi Aich Formation is fluvial to deltaic somewhat influenced by marginal marine environment. It is made of intercalation of sand, shale and carbonate with minor occurrence of anhydrite. In BGR-1 well, this formation flowed about 125 BOPD. Porosity is 9 to 11%.

Berriasian to Aptian isopach mapping exhibits a thickening tendency laying within Jerba trough, described earlier in Upper Jurassic and continued to be active during Early Cretaceous time. A clear change from carbonate dominated depositional setting to dominated siliciclastic environment was seen. Obviously, the occurrence of clastics was a precursory during Late Jurassic time (Figure 4). Small oil fields were found in Lower Cretaceous deposits (carbonate and clastics facies) within Jerba Island. Oil was producing from Robbana and Mazrane. Porosity is varying between 11 and 21%. This area with proven petroleum system is ranked as high confidence.

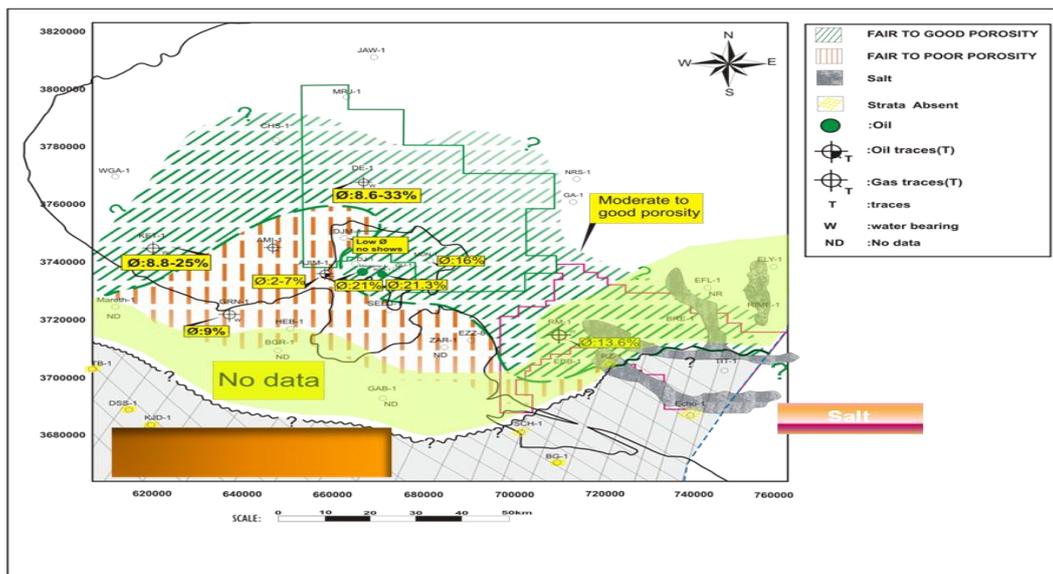


Figure 4. Lower Cretaceous (Berriasian - Aptian) Approximate Reservoir Potential Extension

The Zebbag Formation is a major hydrocarbon producer in Jeffara Basin. It is the main reservoirs for Ezzaouia and El Biban oil fields. During this period of Late Lower Cretaceous an evident returning into shelf carbonate and evaporate environment marked the end of siliciclastics sequence of Lower Cretaceous. This Formation might be subdivided into three members: The Lower Zebbag: Flowed oil and gas in El Biban field from fractured dolomite inter-bedded with shale and evaporite which may guarantee top seal. (Porosity is around 15%). The Middle Zebbag carbonate: in Ezzaouia field porosity in fractured dolomite is about 20%. The Middle Zebbag Evaporite and tertiary sediments are top seal. The Upper Zebbag: Dolomite and limestone eroded in Ezzaouia field but flowed CO<sub>2</sub> gas mainly and condensate in Bregat-1 well. This member is capped locally by Cretaceous shale or younger series.

Source Rocks

At least two petroleum systems are recognized in the studied area, each with multiple reservoir- seal pairs. Hydrocarbon indications and accumulations are known to occur in Jurassic and lower Cretaceous sandstones (Figure 5). Multiple potential source rocks are identified and are considered suitable for hydrocarbon generation and expulsion. A regional evaluation has been undertaken to review the hydrocarbon prospectivity of the Djefara basin (Table1).

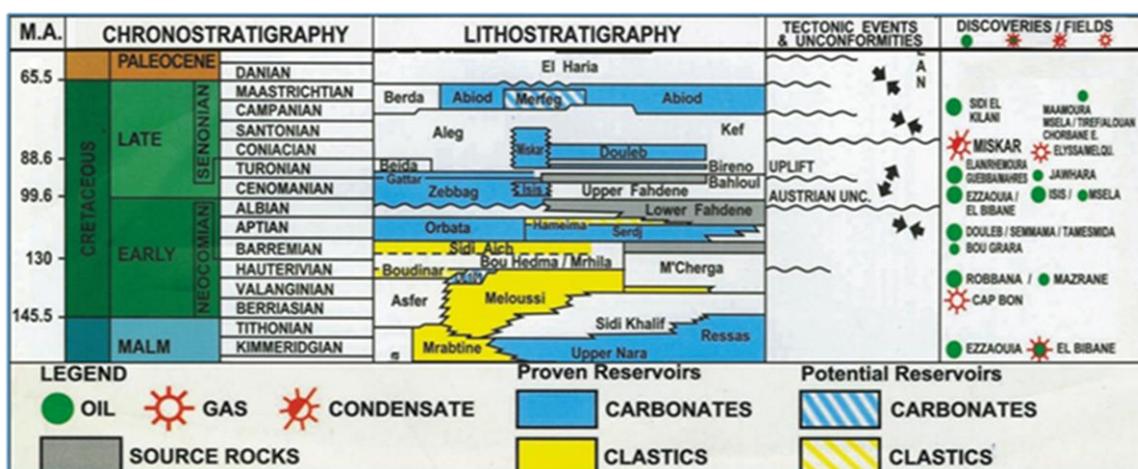


Figure 5. petroleum system in studied area

Table1. Source rocks characteristics in Djefara basin (Saidi Moncef (2010))

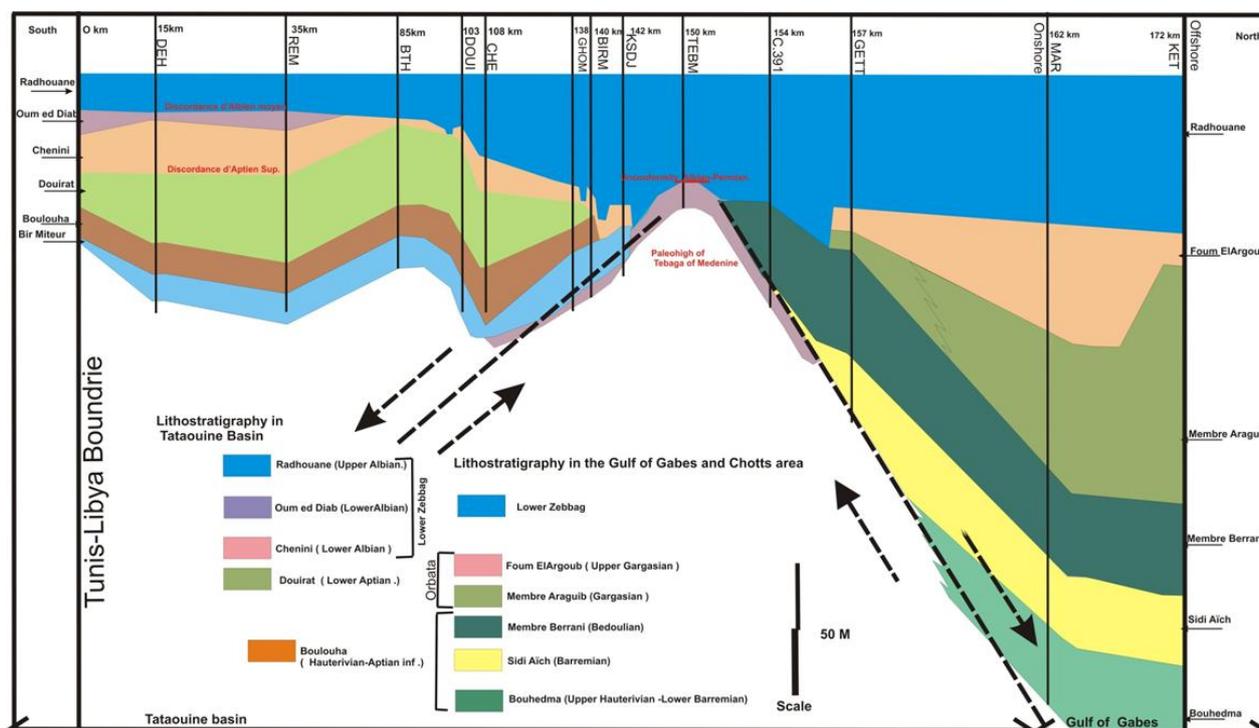
	Thickness (m)	TOC %	PP (kg/t)	Maturity (°c)
Permian	100	0,290-09,18	0,13-31,19	421-442
Rehach /Azizia	14	0,02-5,65	0,08-13,0	428-438
Callovian (Smida Fm)	30-50	0,3 -17,38	0,3-77	415-448
AB-CE (Zebbag Fm)	10_20	0,10-17,25	0,1-55	425-450

## Outcrop study and correlation

The Early Cretaceous sedimentary succession that is exposed in the Jeffara escarpment can be subdivided into two parts according to the main lithology. Siliciclastic deposits dominate the lower part of the sedimentary sequence whereas carbonates dominate the upper part.

The Boulouha formation show particular sediment of Hauterivian-Bedoulian age with estuary and deltaic facies including many repeated layers of sandstone, Clay and dolomite. A maximum thickness of 72 m has been measured in the Merbah el Asfer section. The identification of abundant Brachiopodes with Bedoulian age, in the upper part of the Boulouha formation in Bir Miteur section, provide a stratigraphic correlation between Chotts and Dahar area, southern of Tunisia (Ferjani et al., 1993, Bouaziz, 1986; Dridi et al., 1994, Dridi and Maazaoui, 1998; Denis et al., 1999; Ahmed et al., 1999; Dridi., 2000; Dridi and Maazaoui, 2003; D. Kent Ecumed Petroleum (2001) / (2003); Mejri et al., 2006). The Boulouha formation is the lateral equivalent of the Bouhedma, Sidi Aïch and lower Orbata formations identified in Southern and Northern Chotts sections.

The Douirat formation show particular sediment of Middle Aptian (Gargasien) age with deltaic facies including many repeated layers of sandstone, Clay and dolomite. The Douirat Formation has a maximum thickness of 110 m near Tataouine. Its base is marked by channelised and cross-stratified fine sandstone and silicified wood. The Douirat formation is the lateral equivalent of the Upper Orbata formation identified in Southern and Northern Chotts sections. The Middle Albian, in Dahar area, is composed from sandy to shaly coarsening-upwards sequences of the Chenini formation. The sandstones layers exhibiting cross-stratification indicating a fluvial transport. Wood debris is locally present. Lateral correlation of the sections between Chotts and Dahar areas result in the interpretation of the platform depositional architecture as a function of accommodation and sediment supply of the lower Cretaceous in Southern Tunisia. (summarised in Figure 6). Lateral and vertical facies changes reflect water-depth and paleoenvironmental variations, which are interpreted in connection with relative sea-level changes. Lower Cretaceous sediments are distributed throughout the Dahar area, Jeffara area and Chotts Basin. They are absent near in Tebaga high area and to the East of Tataouine Town. The section has been reduced by intra unconformities with abnormal contact Permian-Upper Albian series in Tebaga high area.



**Figure 6.** lateral evolution of the lower cretaceous deposits showing the impact of the paleohigh of tebaga medenine in the paleogeographic evolution of southern tunisia (deh: dehibat; rem: remada; bth: bir thelathine; doui: douiret; che: chenini; gom: ghomrassen; birm: bir miteur; ksdj : ksar djoumaa; tebm: tebaga de médénine ; c391 : côte 391 ; gett : guelb ettine ; mar : mareth (onshore) et ket : kettana (offshore)).

## Petroleum implications

The main interest is better understanding the petroleum implications from the geological study of the Lower Cretaceous. The multidisciplinary approach helps decipher the roles of tectonic and sea level change in source and

reservoir rock deposition, seal developments of El Beida evaporates and marine shale of Aleg formation, source-rock maturation (e.g., Khchem El Mit Formation) and subsequently hydrocarbon migration toward final traps. It is creditable of noting that the substantial discoveries of BGR1, EZZ1, EBB1, ROB-1, Ras Marmour-1 and MOZR1 oilfields extending from the Djerba region to the Libyan border, have largely encouraged petroleum exploration of Lower Cretaceous series and multidisciplinary geological studies (figure 7 and 8).

The sandstones and dolomites levels of the Meloussi formation present good oil and gas shows and tested 900 BOPD and 84 MCFPD of gas in Robbana 1 well. In Mozrane well, several sand intervals tested oil with an average rate of 600 BOPD. The Sidi Aïch fine-grained sandstone formation tested 150 BOPD in Boughrara 1 well. The oil occurs in thin bedded, fine grained sandstones of the lowermost part of the Sidi Aich formation. Porosities are moderately good, but the reservoir is relatively heterogeneous.

The Zebbag formation contains and produced the vast majority of Cretaceous hydrocarbons found in the study area, such as the Ezzaouia (EZZ-1) and El bibane fields (EBB-1). The Zebbag reservoir sections are mainly fractured, vuggy and brecciated dolomite. In Ezzaouia field, the porosity ranges from 5 to 40% (matrix porosity up to 26%) and the average permeability is 5 Md. Net reservoir thickness is 40 m. seal is provided in this field by Eocene shales.

Small oil fields were found in Lower Cretaceous deposits (carbonate and clastics facies) within Jerba Island. Oil was producing from two wells and the porosity is varying between 11 and 21% (figure 7).

The Barremian Sidi Aich Formation showing a fluvial to deltaic extend influenced by marginal marine environment. It is made of intercalation of sand, shale and carbonate with minor occurrence of anhydrite. In BGR-1 well, this formation flowed about 125 BOPD. Porosity is 9 to 11% (figure 8).

The Middle Zebbag member reservoirs (Cenomanian) exhibit a Maximum porosity varying between 10 to 20%. The common values are about 10 to 12% (figure 9).

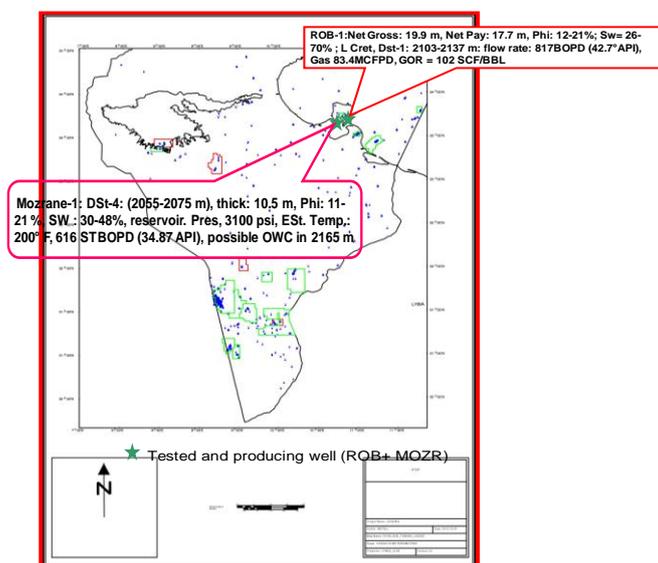


Figure 7. Petrophysical and Hydrocarbon Data of Meloussi formation in Jeffara Area

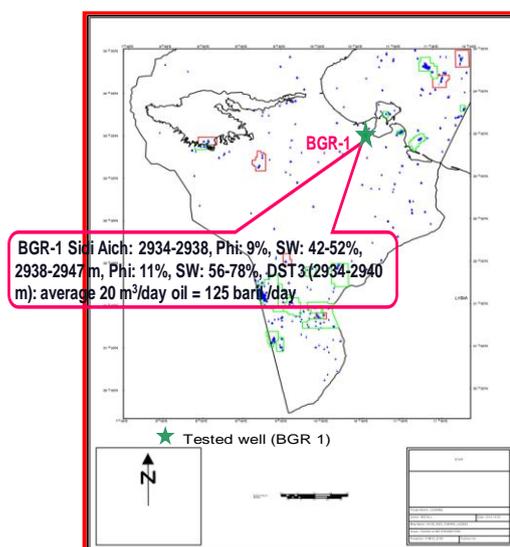


Figure 8. Petrophysical and Hydrocarbon Data of Sid Aich formation in Jeffara Area

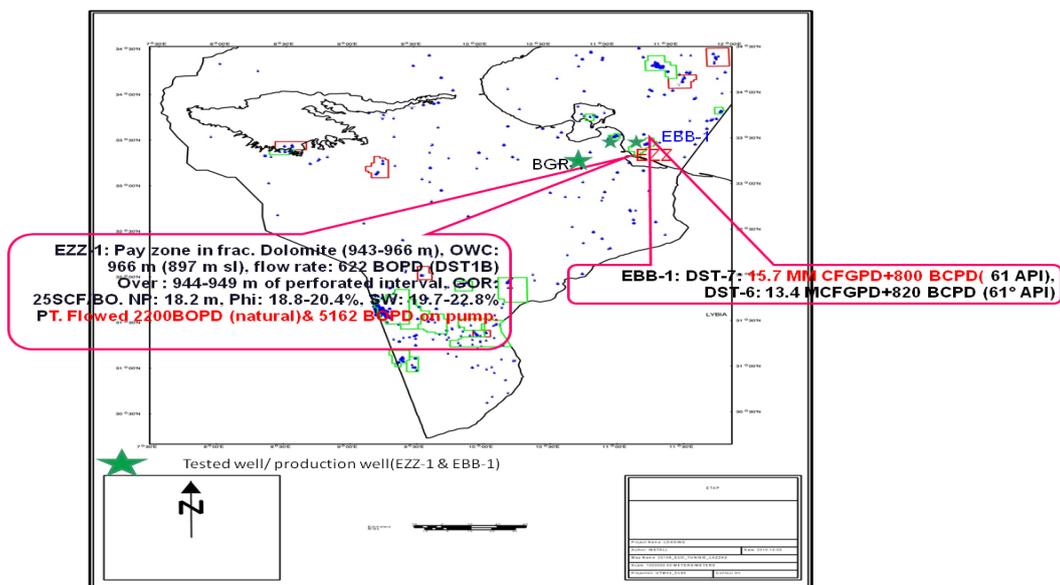


Figure 9. Petrophysical and Hydrocarbon Data of Zebbag reservoir (Albian-Cenomanian) in Jeffara Area

### CONCLUSION AND RECOMMENDATION

Petroleum system is approved: Carnian and Callovian source rocks, reservoirs sandstones and carbonate within Late Jurassic and lower Cretaceous; Seals is provided by interbedded shales and evaporates or younger claystones (Eocene in Ezzaouia Field). Outcrop section of lower Cretaceous with visual good porosity and

where sand bodies are intercalated between shale or evaporates layers could be attractive targets in subsiding domain to the East surrounding Djerba Island; where we have open block for example: AJIM (E1), LA SKHIRA (E3), ZAMA (E4) and Guellala (E5) (Figure 10). Generally, discovered oil pools are located on horst structures, but grabens, where exploration potential remain approximately unexplored could be considered as a new exploration features in this sector; however we think that exploration in graben still under explored. Deep hydrocarbon objectives, such as Triassic reservoirs, main hydrocarbon producer in Ghadames basin are still under assessed in this Gabes Gulf area. Moreover play evaluation exhibits proven and potential petroleum systems, encountered within Jurassic and Lower Cretaceous series and Cenomanian carbonates are locally ranked.

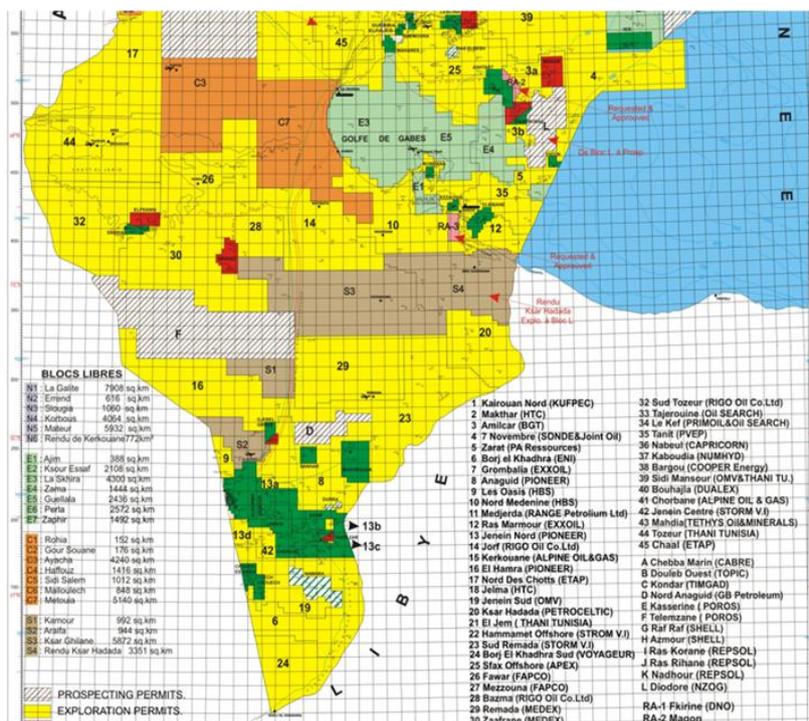


Figure 10. Tunisia open block map

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