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Exploration History of Messla Oil Field, Sirt Basin, North Central Libya

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تاريخ الاستكشاف في حقل المسلة النفطي، حوض سرت، شمال وسط ليبيا

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قسم هندسة النفط، كلية الهندسة، جامعة مصراته، مصراته، ليبيا.

Abstract

The exploration history in Libya started in the western part of Libya near the border to Algeria by Esso Company one of the Seven Sisters hopefully that the oil accumulation will extend from El Hasi El Masoudi in Algeria. The first well drilled (Wildcat) was Al Atshan well. There were only oil shows in this well. It was plugged and abandoned. Then Esso Oil Company was given a concession in Sirt Basin in the early fifties by the Libyan Ministry of Petroleum. The exploration history in Messla Oil Field started by drilling the wildcat HH1-65. The field was discovered in 1971 and was located in the southeastern part of the Sirt Basin approximately 40 km northwest of the supergiant Sarir Oil Field. Although in an early stage of development, the field is estimated to contain approximately 3.25 billion bbl. of original oil-in-place. The field was a seismically defined stratigraphic accumulation located on the east-dipping flank of a broad Precambrian basement high. The reservoir is in the Lower Cretaceous fluvial Sarir Sandstone, which wedges out westward on the basement and is truncated by a basin-wide unconformity at the base of the capping Upper Cretaceous marine shales (considered to be the source rocks) and by the seal Busat Formation (Anhydrite Cap). The reservoir consists of two sandstone units separated by a continuous shale bed (Red Shale). Porosity values average 17% and the permeability 500 md. The oil column averages approximately 90 *ft.*, and is productive from an average depth of 8,800 *ft*. Over 200 km^2. Early 1978 production is in excess of 100,000 *bbl/d* of 40° API oil with a cumulative production of 45 million *bbl*.

Keywords: *Messla Oil field, Exploration, Geophysics, Sarir Sandstone, Sirt Basin, Libya.*

الملخص

بدأ تاريخ الاستكشاف في ليبيا في الجزء الغربي من ليبيا بالقرب من الحدود الجزائرية من قبل شركة Esso إحدى الشقيقات السبعة على أمل أن يمتد تراكم النفط من الحاسي المسعودي في الجزائر إلى ليبيا. حيث كان أول بئر تم حفرها (Wildcat) كان العطشان ولم يكن هناك سوى النفط في هذا البئر لذا تم توصيله وتركه. ثم حصلت شركة اسو أويل على امتياز في حوض سرت في أوائل الخمسينيات من قبل وزارة البترول الليبية. بدأ تاريخ الاستكشاف في حقل مسلا للنفط من خلال حفر الاستكشافي HH1-65. تم اكتشاف الحقل في عام 1971 وكان يقع في الجزء الجنوبي الشرقي من حوض سرت على بعد 40 كم شمال غرب حقل سرير النفطي العملاق. على الرغم من أن الحقل قدر في مرحلة مبكرة من التطوير بحوالي 3.25 مليار برميل من الزيت الأصلي في المكان. كان الحقل عبارة عن تراكم تراكيب مُحدَّد زلزالياً يقع على الجانب الشرقي للغمس في أعلى مستوى من قبو ما قبل الكمبري. يقع الخزان في الحجر الرملي السفلي من العصر الطباشيري Sarir الرملي، الذي يتدرج غربًا في الطابق السفلي ويتم اقتطاعه من خلال حالة عدم اتساق على مستوى الحوض عند قاعدة الصفائح البحرية العليا الطباشيرية (التي تعتبر صخور المصدر) وبواسطة الختم Busat تشكل (Anhydrite) تمثل غطاءً. يتكون الخزان من وحدتين من الحجر الرملي يفصل بينهما سرير من الصخر الزيتي (Red Shale). سُجلت قيم المسامية

عند 17٪ والنفاذية 500 md. وبلغ متوسط عمود الزيت حوالي 90 قدمًا، ويتم إنتاجه من متوسط عمق 8,008 قدمًا. لأكثر من 200 كم^2. في أوائل عام 1978 كان الإنتاج يزيد عن 100,000 برميل نفط في اليوم من زيت درجة 40 API مع إنتاج تراكمي قدره 45 مليون برميل.

الكلمات الدالة: حقل مسلة النفطي، الاستكشاف، الجيوفيزياء، السرير الرملي، حوض سرت، ليبيا.

1. Introduction

In 1961 British Petroleum, in partnership with Nelson Bunker-Hunt, discovered the multi-billion barrel Sarir C-Main field. Production was extended northward with smaller but significant discoveries in 1963 of C-North, and in 1964 of the Sarir L field (Sanford, 1970) (shown in Figures 1and 2).

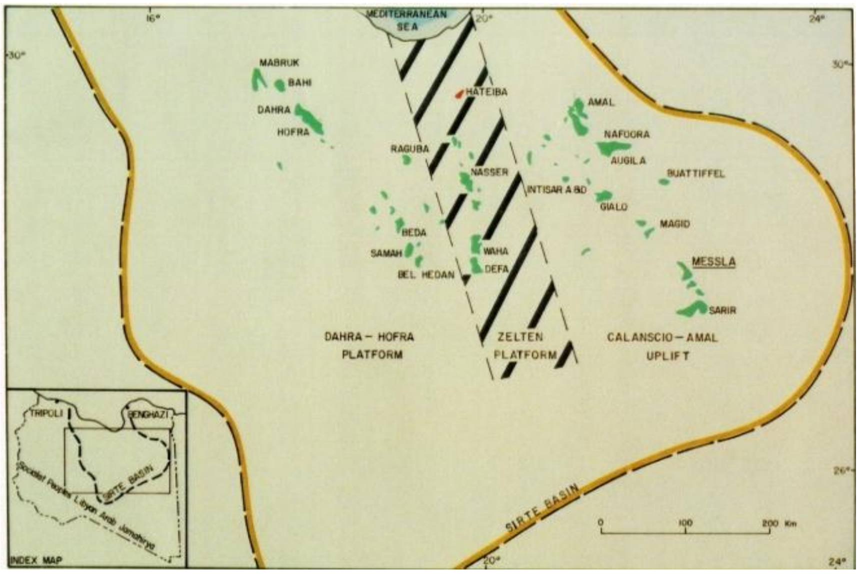

Figure 1. Location of Messla Oil Field (orange arrow) (Clifford *et al.*, 1980)

In 1971, HH1-65, the 38th wildcat in 8,200 km^2 area of Concession 65, was drilled approximately 8 km north of the "L" field. HH1 was located on a seismic-mapped southeasterly plunging nose. The location was based on the geologic concept that the Lower Cretaceous Sarir Sandstone, productive in the "L" field, wedged out toward the west and northwest. direction a prominent Sarir bald basement high had been encountered by earlier wildcats. The discovery well penetrated 110 *ft*. of net oil bearing Sarir Sandstone through the interval 8,768 to 8,896 *ft*. and was potential-tested at a rate of 10,900 *bbl/d* of 38° API oil (Clifford *et al.*, 1980). Subsequent delineation drilling showed the accumulation to be stratigraphically trapped by a westerly pinch-out of the Sarir Sandstone onto the basement, in conjunction with a regional unconformity at the top of the Sarir Sandstone

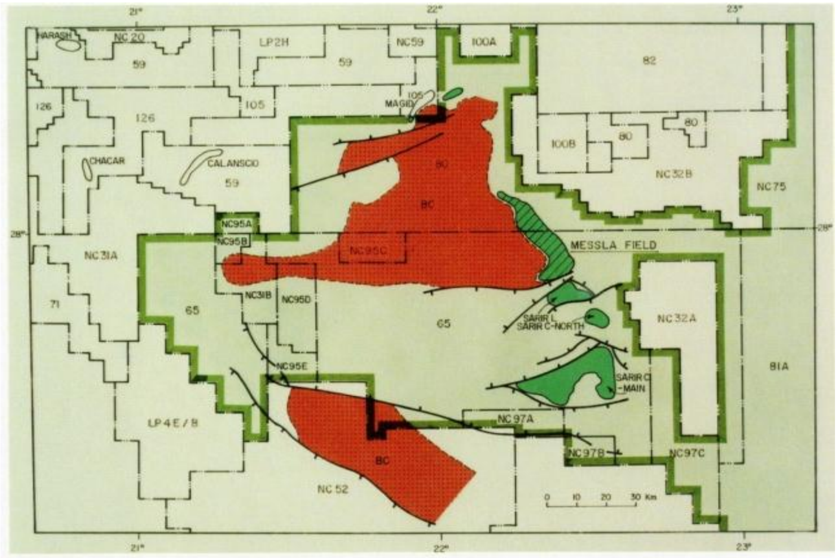

Figure 2. [Color] Index map southeast Sirt basin showing location of Sarir and Messla fields, broad basement highs (BC), and concession boundaries (Clifford *et al.*, 1980)

2. Structure

The Messla field lies along a broad northeast dipping structural flexure that houses a weak eastward plunging anticlinal nose near its southern extremity. Over a major part of the field the structure is a homocline, with a rather constant strike of N 40° W and eastward dip of 0.5 to 1°. The gentle dipping homocline terminates at a regional syncline 15 *km* northeast of Messla (Clifford *et al.*, 1980). (Figures 3, 4, and 5). The variations in strike across the field, as indicated by contours on the unconformity surface (Figure 6, are tentatively considered to be eastward flowing drainage patterns rather than structural depressions, as these strike variations are not evident on an intra-Sarir Sandstone zone. As much as 100 *ft.* (30 *m*) of possible erosion has occurred in these narrow "channels." A "channeling" interpretation is not, however, supported by all the data, and until additional drilling in these features is available, other causes, particularly faulting, are believed possible. Faulting has not been recognized within the Messla field, which is surprising due to its frequency in the Sarir fields (El-Hawat *et al.*, 1993). Only at the southern boundary of the field is there a defined zone of westerly trending cross faults. These faults, downthrown on the south side, interrupt the southern flank of the nose and parallel the shallow syncline which separates Messla from the anticlinal and fault-controlled "L" field (Clifford *et al.*, 1980).

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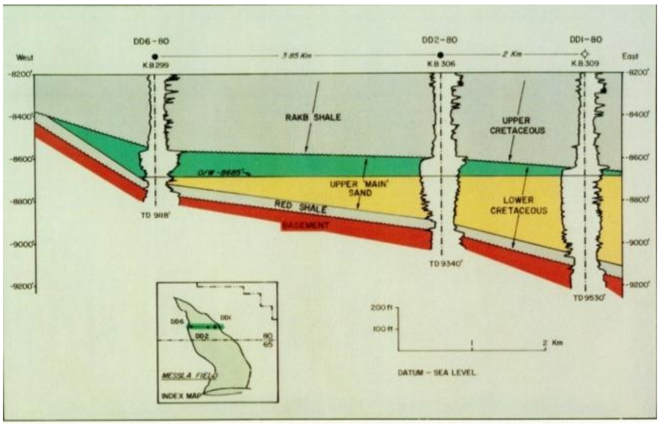

Figure 3. [Color] West to east cross section of line A-A^prime, Messla oil field, showing wedge out and truncation of Sarir Sandstone (Clifford *et al.*, 1980).

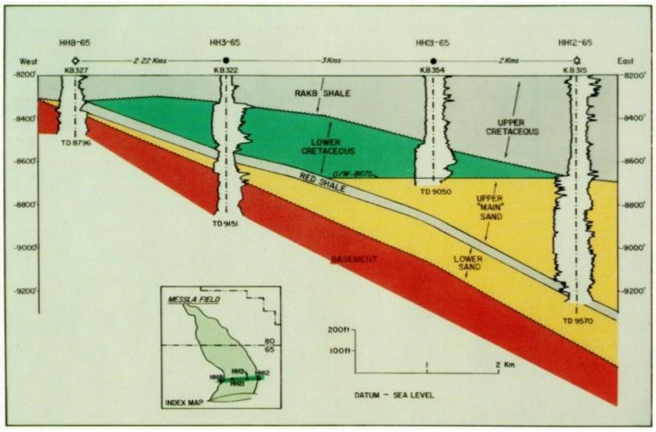

Figure 4. [Color] West to east cross section of line B-B^prime, showing wedge out and truncation of Sarir Sandstone (Clifford *et al.*, 1980)

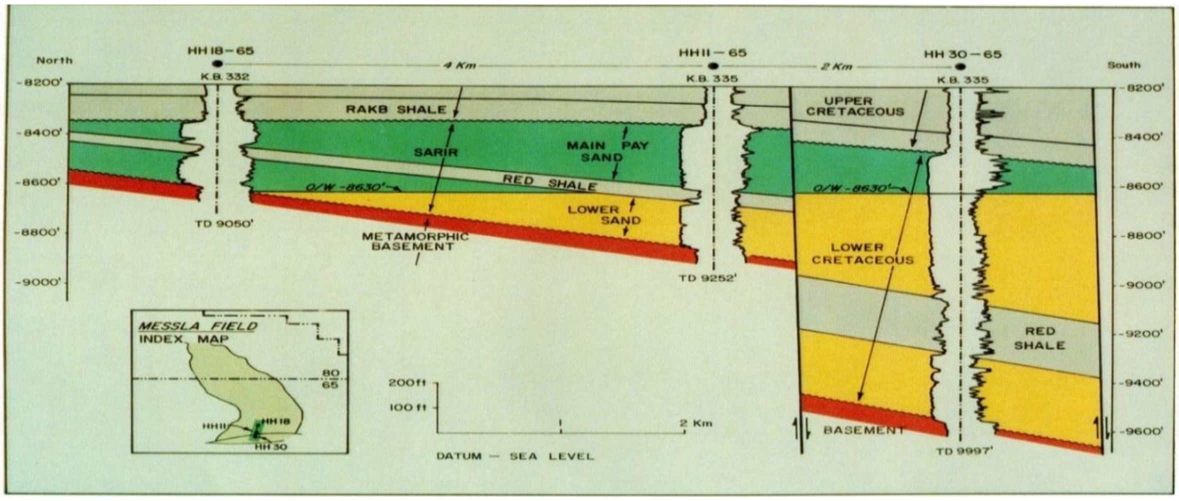

Figure 5. [Color] North to south cross section of line B-B^prime, Messla oil field, showing a partly truncated and faulted section of Sarir Sandstone (Clifford *et al.*, 1980)

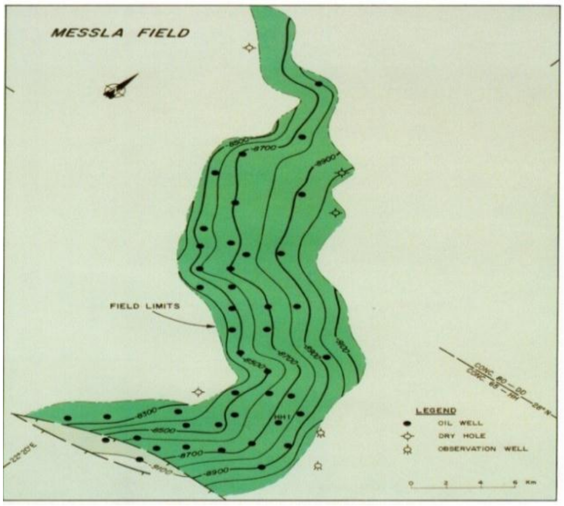

Figure 6. [Color] Intra-Sarir structure, Messla oil field, Libya.

3. Geophysics

Various geophysical surveys were carried out in the years prior to the drilling of HH1-65. Airborne magnetometer and gravity surveys showed an eastward plunging basement nose in the general area of the field, (Abadi, 2002). Reconnaissance single fold reflection and basement refraction seismic refined the interpretation of the nose but it was not until the 1969 completion of a 600% analog reflection survey that a comprehensive deep structural picture emerged (Clifford *et al.*, 1980). The additional information obtained from the initial discovery and early delineation drilling was used in a 1974 reinterpretation of the existing seismic data, which yielded a detailed structure map of a deep time event associated with the top of the Upper Cretaceous Rakb-4 Formation. This map forms the basis for the structural interpretation of the Messla field, and only a slight modification in its detail resulted from a 208 km, 1,200% digital reflection survey in 1975. Subsequent drilling has confirmed the map's reliability. The field area is characterized by good reflection results (as shown in Figure 7) (Clifford *et al.*, 1980).

4. Stratigraphy

The stratigraphic sequence in the Messla field is divided into two major depositional periods by a pronounced intra-Cretaceous unconformity (Gras and Thusu, 1998), (as shown in Figure 8). The pre-unconformity sediments of the Lower Cretaceous age are predominantly non marine, and average 500 *ft.* (152 *m*) in thickness. The post-unconformity Upper Cretaceous and Tertiary form a thick succession of deep-marine to near-shore deposits, averaging 8,800 *ft.* (2,682 *m*) in thickness. Significant lateral facies variations within the field occur only in the Paleocene, which exhibits a strong north to south facies change (Peter and Dana, 2003).

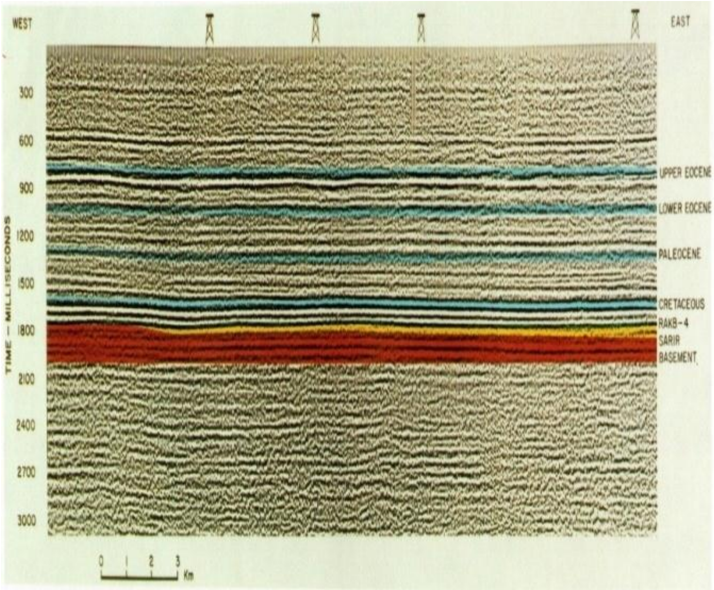

Figure 7. [Color] Seismic line showing wedge of Sarir Sandstone and gentle eastbound dip of flank of basement high (Clifford *et al.*, 1980)

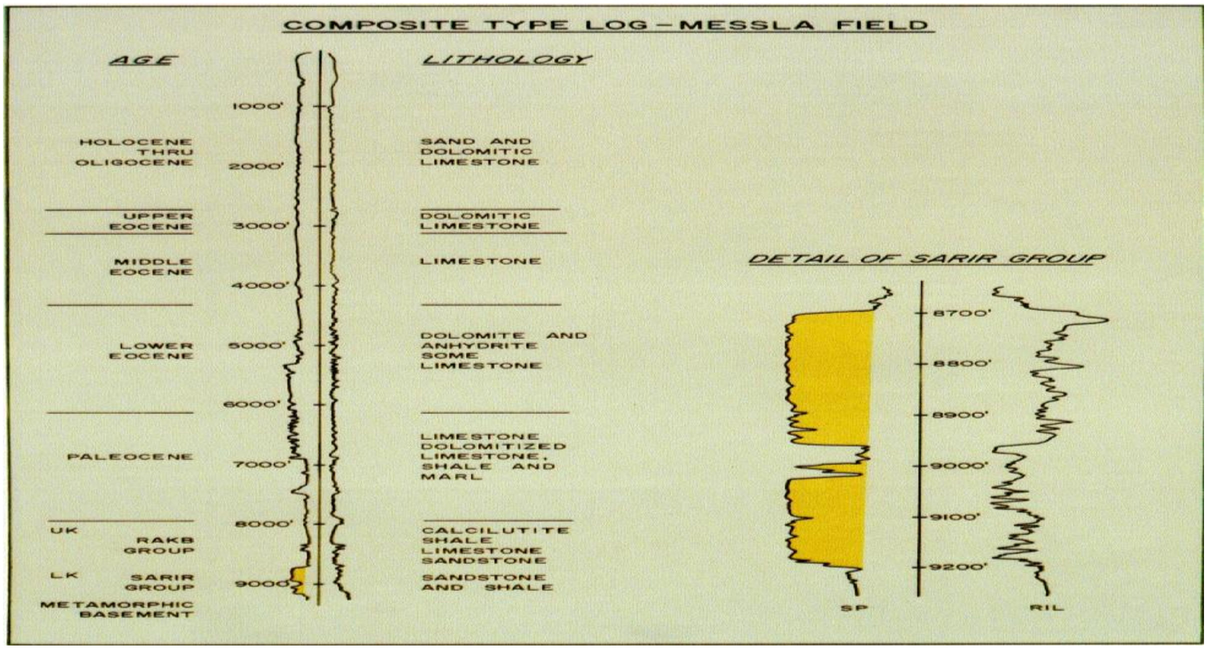

Figure 8. [Color] Stratigraphic column at Messla field, Libya (Clifford *et al*., 1980)

5. Reservoir Properties

Petrographic and SEM analysis demonstrate that a series of early cementation and compaction events, in combination with late burial diagenesis, have occluded most of the porosity in these sandstones (as shown in Figures 9 and 10). Early chlorite rims, pore-filling chlorite, calcite, dolomite, and anhydrite cements have pervaded the primary pore network. Bitumen coatings

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on chlorite rim cements record an early episode of oil migration. Consequently, most diagenesis post-dated oil migration. Sublitharenites containing rock fragments have the highest frequency of chlorite cement. This suggests that rock fragments sourced the iron and magnesium for the authigenic chlorites in Sarir sandstones (Tucker, 2001). Following precipitation of chlorite and pervasive cementation by non-Ferroan carbonates and anhydrite, the influx of corrosive fluids created secondary porosity by partial to complete dissolution of labile framework grains and intergranular cements. These secondary pores have been cemented with kaolinite and later Ferroan carbonates. Hence, this dissolution event did not improve reservoir character (Koscec and Gherryo, 1998). Late burial diagenesis of Sarir siliciclastics, by analogy with other Gulf of Sirt basin formations, occurred at elevated temperatures (100 to 150°C) based on the presence of abundant detrital feldspars. The pervasive distribution of late pyrite in some Sarir Formation cores provides evidence of thermochemical sulfate reduction. The Sarir Formation diagenetic system is inferred to have been semi-closed because components needed for the formation of several diagenetic phases (e.g., chlorite, kaolinite, and pyrite) appear to have been derived internally. Diagenetic alteration of rock fragments, detrital feldspars, and authigenic anhydrite liberated ions that re-precipitated in situ as cements. However, the sodium required for albitization, as well as the calcium and magnesium needed for precipitation of pervasive carbonate cements, most probably had an extra formational source (Moore, 2002).

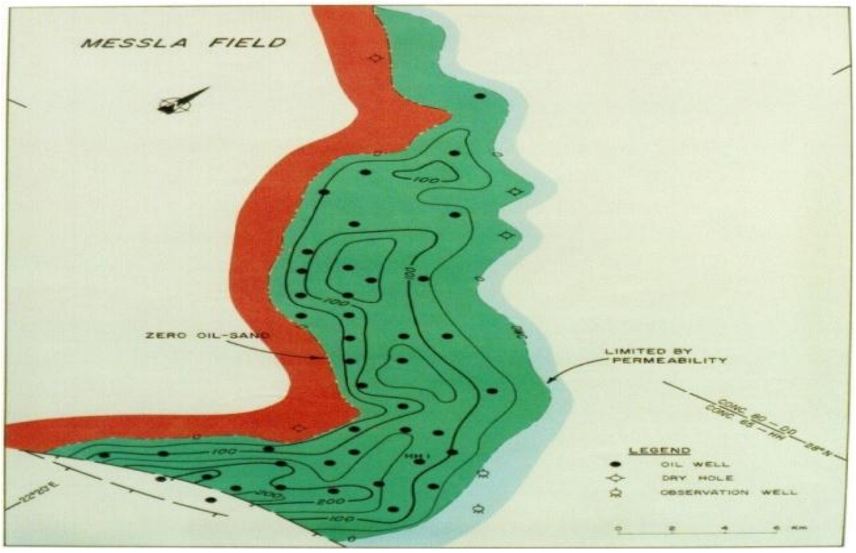

Figure 9. [Color] Net pay Isopach map, Sarir Sandstone, Messla field, Libya.

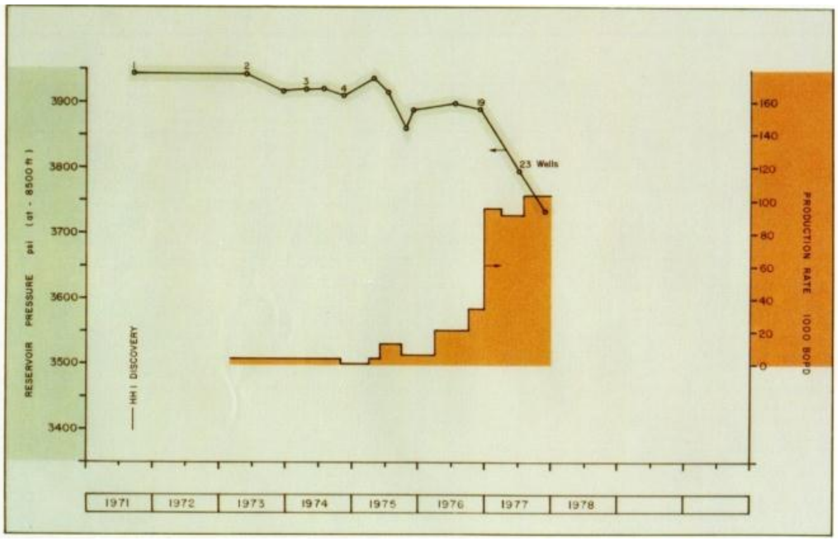

Figure 10. [Color] Production graph of oil production in Messla field, Libya, beginning with the discovery of HH-1 in 1971 (Clifford *et al.*, 1980)

5. Conclusion

The nature of the sandstone facies provided reasonable reservoir rocks. The shale facies of the Red Shale member represents a well-developed break between the Lower Sarir Sandstone and Upper Sarir Sandstone members; it also provides a good seal for the underlying sandstone of the Lower Sarir Sandstone. The nature of the shale facies, (i.e. lack of organic content, and presence of oxidizing conditions indicated by iron oxides color), indicate that they are not a significant source of hydrocarbons.

However, in the open system of nature well developed ideal models are limited; the studied Sarir sequence in the Messla area can be considered, in a general since, an example of petroleum producing fluvial deposits.

This study, hopefully, enhances the understanding of the nature of the rock sequence in an important giant oil field. It is a contribution to the geology of the region; and it can be of great help in the exploration of similar examples locally around the Messla high and regionally. Although, this study reasonably covered the Sarir Sequence in the Messla Oil Field, further follow-up study, that covers more wells and expands to adjacent areas, will be very useful.

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