Reassessment of Source Rock Potential and Charge Effectiveness in the Cyrenaica, NE Libya

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Article information **Abstract**

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In this article, the source rock potential in the oil-bearing areas of the north-eastern parts of Libya is reviewed. The specific areas which are examined are the Cyrenaica Platform, the Ash Shulaydimah Trough and the Al Jabal al Akhdar. The regional Rock Eval geochemical data has been used in conjunction with the well-based Rock Eval data as well as outcomes from exploratory wells to provide information on the Silurian to Paleogene potential source rock distribution and quality. The Paleocene/Eocene source rocks possess excellent quality locally, with hydrogen index values ranging from 700 to 970 mg of HC/g TOC and approximately 1.9 to 8.7 weight % organic carbon. Generally Cretaceous periods show moderate source quality with TOC levels ranging between 0.6 and 2.2wt% and HI levels of 55 to 183 mg HC/g TOC. Locally hydrocarbon generation has been confirmed by well control. This includes a Devonian sandstone gas show which is thought to originate from Silurian shales beneath. Nonetheless, no commercial discoveries have so far been made. Thermal maturity patterns of the source rocks in the area are very varied due to various short-term burial episodes and the area being uplifted after the deposits had been laid down. This occurs specifically in Al Jabal al Akhdar and the Ash Shulaydimah Trough. In the Cyrenaica region, petroleum system effectiveness is limited primarily by small kitchen volumes, restricted migration distances, and reduced hydrocarbon charge, rather than by the absence of organic-rich strata.

Introduction

Approximately 70% of the world's hydrocarbon resources occur within the former Tethyan realm, reflecting the widespread development of organic-rich marine source rocks during Mesozoic and early Cenozoic times (Baudin, 1995). The geological province of northeast Libya is distinct from both southern Libya and the Mediterranean coastal region. In northeastern Libya, the Cyrenaica Platform, the Al Jabal al Akhdar (Green Mountain) structural uplift, the Ash Shulaydimah Trough, and the Marmarica sub-basin belong to a single long-lived structural basin that dates back to the Paleozoic era. The geological structure of the area is the result of repeated phases of marine sedimentation, subsidence, and tectonic uplift, and this complex evolution has had a significant influence on hydrocarbon generation and accumulation. According to Albriki et al. (2021), the Cyrenaica Platform has

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undergone multiple phases of tectonic reactivation, resulting in structural compartmentalization and variable burial histories across the region.

The stratigraphic framework of northeastern Libya extends from the Paleozoic to the Cenozoic and includes several geological intervals with proven and inferred hydrocarbon source rock potential. The regional stratigraphy and the distribution of potential source rocks, reservoir rocks, and seal units are shown in the stratigraphic column in Figure 2. Despite the presence of several geochemically favourable intervals, hydrocarbon exploration in Cyrenaica has so far not resulted in any significant commercial discoveries. The mere presence of source rocks alone does not ensure the development of a functioning petroleum system (Campbell, 1991; Baird et al., 1996).

In northeastern Libya, where exploration activity has historically been limited, geological conditions are the primary controls on hydrocarbon generation and preservation. The main factors controlling hydrocarbon prospectivity include basin geometry, burial depth, thermal regime, and tectonic modification following deposition. Volcanic and geological processes, particularly uplift, erosion, and faulting, can strongly influence petroleum systems. For example, erosion reduces the amount of organic matter that can be buried and therefore limits hydrocarbon generation. A full evaluation of the region therefore requires an integrated approach combining burial history, structural evolution, and organic geochemical data.

The source rock potential of Cyrenaica spans stratigraphic intervals from the Silurian to the Paleogene. Silurian shales of North Africa are known for their high organic content and can generate hydrocarbons when buried sufficiently deeply. These shales are part of the regional hot shale play. Paleocene–Eocene successions locally contain high organic carbon contents and elevated hydrogen index values, indicating the presence of oil-prone kerogen. Jurassic source rocks contain more oil-prone kerogen than Cretaceous source rocks; however, Cretaceous source rocks are more widely distributed, although they are generally of moderate to poor oil-generating quality. Although high-quality organic-rich shales are present, this alone does not explain the limited exploration success in the region.

Calibration of the petroleum system in northeastern Libya has been aided by data from two exploratory wells. A Devonian sandstone gas show in well B1-2 is interpreted to have been sourced from underlying Silurian shales. In addition, oil occurrences in thermally overmature reservoir rocks indicate that hydrocarbon generation and migration have occurred locally. The offshore Benghazi well A1-NC-120 is believed to have received hydrocarbons from Cretaceous source rocks, possibly of Early Cretaceous age. These examples suggest that petroleum systems in Cyrenaica are present but inefficient, possibly due to low petroleum volumes, short migration distances, ineffective traps, or poor preservation.

The petroleum systems of the Eastern Mediterranean and northeastern Libya are therefore controlled by small, scattered, and discontinuous source rock bodies. This reflects the effects of tectonism, short-lived thermal histories, and variable maturation. Neogene uplift and erosion caused premature termination of maturation, breaching of traps, and loss of hydrocarbons (Bosworth, 2017). Even high-quality source rocks require sufficient burial and preservation to generate commercial accumulations.

Recent integration of Rock-Eval data, exploration results, well data, and geochemical and structural information has highlighted the need to reassess the factors controlling hydrocarbon generation and charge in Cyrenaica. Although source rocks are generating hydrocarbons, regional tectonic and geological processes strongly restrict effective generation, migration, and trapping.

Geologic Setting

Northeastern Libya forms a distinct geological province within the former Tethyan realm. The region comprises the Cyrenaica Platform, the Al Jabal al Akhdar uplift, the Ash Shulaydimah Trough, and the Marmarica sub-basin, all of which are components of a single long-lived Paleozoic structural basin. The area has undergone repeated phases of marine deposition, subsidence, and tectonic uplift, creating a complex structural framework that strongly influences sediment thickness, burial history, and hydrocarbon preservation.

The stratigraphic succession spans from the Paleozoic to the Cenozoic and contains multiple intervals of potential source, reservoir, and seal rocks. Structural reactivation of the Cyrenaica Platform has produced strong compartmentalization, with variable burial depths and localized depocenters that control thermal maturity patterns. Uplift, erosion, and faulting during later tectonic phases, particularly in the Neogene, have further modified the basin, limiting the size of effective hydrocarbon kitchens and restricting migration pathways. As a result, petroleum systems in northeastern Libya are small, discontinuous, and strongly controlled by tectonic architecture rather than by source rock presence alone.

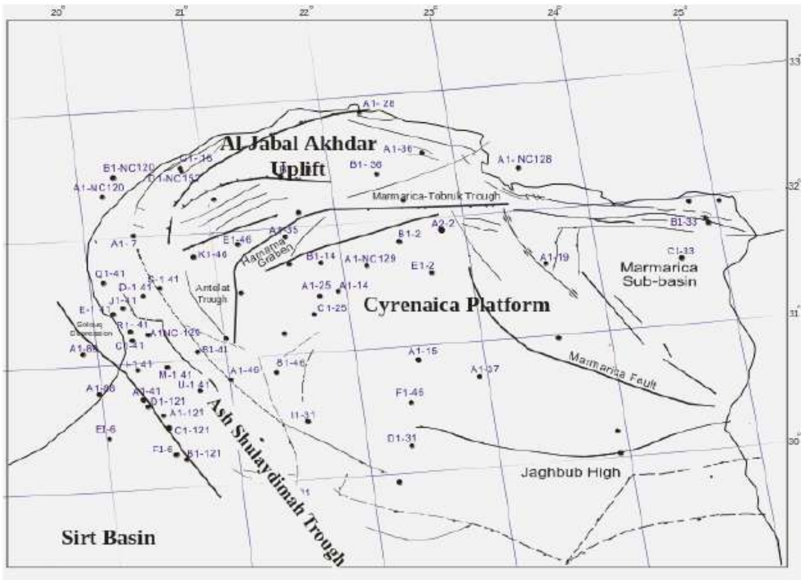

Figure 1. Structural map of NE Libya showing the main tectonic elements and well distribution with location of studied wells.

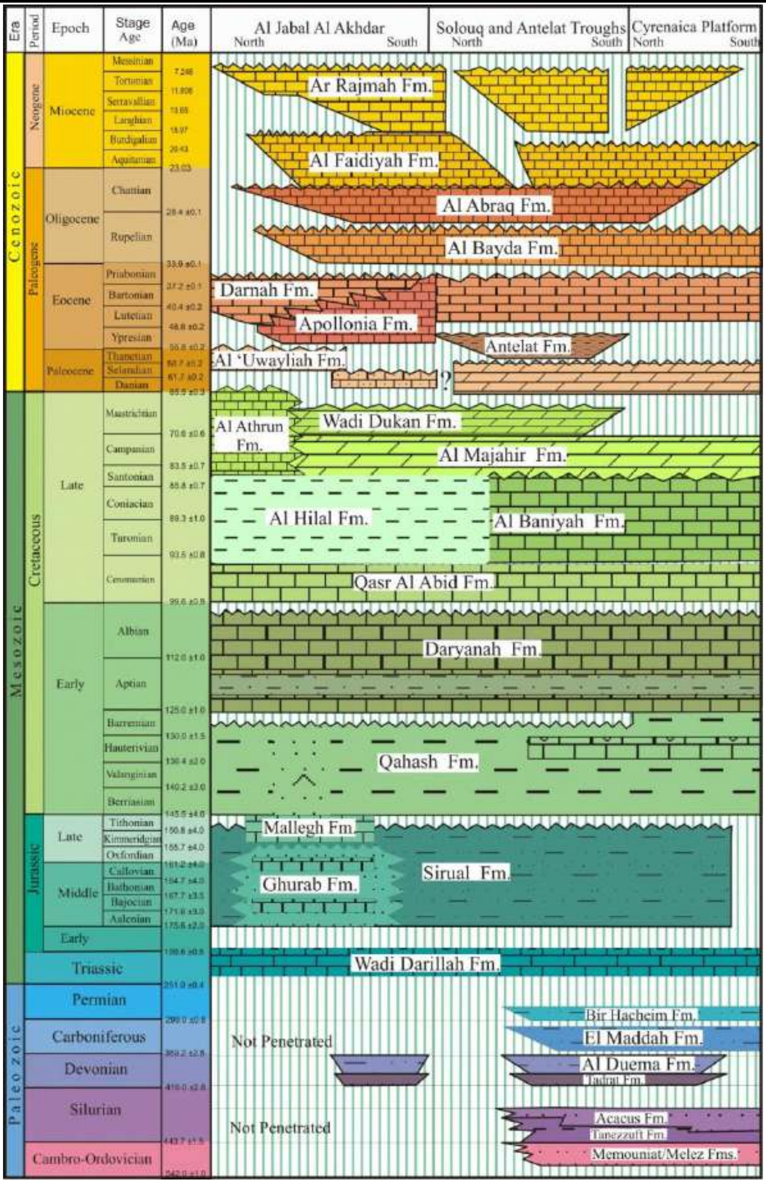

Figure 2. Stratigraphic chart of NE Libya, (Hassan & Kendall, 2014).

Methodology

A review at regional Rock-Eval data ties into lab results from individual wells, along with field observations. More than 35 wells contributed samples; rocks, core pieces, and surface records were included. Geochemical and geological datasets were integrated to assess petroleum system risk, focusing on overall system effectiveness rather than isolated components. These Regional Rock-Eval pyrolysis plots give the minimum, maximum and average total organic content in rocks. The ratio of S2 to S3 pyrolysis peaks was used to assess kerogen quality and hydrocarbon generation potential. These kerogen types are classified by means of the data plotted on these charts. Large scale pyrolysis data are supplemented by regional data sets which include oxygen index, hydrogen index, production index, Tmax, S1–S3 (mg HC/g rock), and TOC (wt%). In the Eocene the kerogen is generally oil-prone as indicated by high HI and S2 values. Cretaceous source rocks are however gas-prone due to a mixture of kerogen Type II and III.

All analysis were obtained by using standard Rock-Eval screening procedures (Espitalié et al., 1985). In organic petrology, the Total Organic Carbon (TOC) content is used as a measure of the original organic richness of the source rock. The HI and OI are used to determine the type of kerogen and the potential of the source rock. Tmax is a measure of the thermal maturity of the source rock.

Results

The geological cross-section extending from southwest to northeast across Libya (Figure 3) shows that the Cyrenaica Platform contains significantly thinner stratigraphic successions than the adjacent northern fault-bounded troughs. This is in comparison to the fault troughs that exist to the north, the Ajdabiya and Ash Shulaydimah troughs. This reduced burial is largely controlled by fault-related structural segmentation. A pronounced structural segmentation of the area is observed, with deeper burial of Paleozoic and Mesozoic ages happening only in local troughs and the thickness and the elevation of the sediments gradually decreases towards the platform's interior. The pattern of maturation of potential source rocks and burial history is primarily controlled by depth of burial and temperature history.

Samples of rock from pyrolysis in the northeastern region of Libya, have shown significant variations in the rock's organic material content, the type of kerogen and the ability of the rock to produce oil. The Silurian, Cretaceous and Paleogene sequences are summarized in Table 1 with respect to their thermal maturity, highest interval and kerogen type inferred from this. Table 1 also contains a qualitative appraisal of the source rock potential of the succession. The relationships between Rock-Eval parameters illustrated in Figures 3 and 4 used guide the ranking of samples in each interval.

A hydrogen index-oxygen index cross-plot for the source rock samples from the North East Libya is presented in Figure 5. Crossplots of the kerogen and vitrinite reflectance values are useful in classifying the type of kerogen and determining the hydrocarbon generation potential (Espitalié and Marquis, 1985). In the available data, it would seem that kerogen of types II and II/III is predominantly found in both Silurian and Cretaceous periods. This analysis indicates that these rocks have moderate potential for oil and gas generation. Paleogene source rocks are primarily associated with Type I to Type II kerogen deposited in restricted marine sedimentary environments. This reflects the presence of hydrogen-rich organic matter capable of generating oil. Stratigraphic units are ranked on a scale which can be numbered according to the distribution of samples and the total weight of organic carbon found in them as shown in figure 4. Before any detailed, well by well assessment, the potential of Cyrenaica Basin is evaluated as a source rock within this framework.

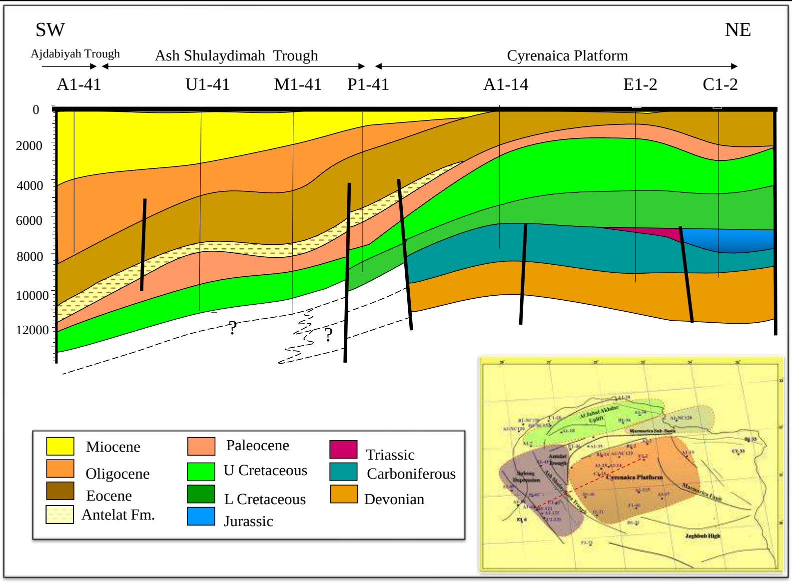

Figure 3. Geological cross-section from southwest to northeast across the Cyrenaica region of northeastern Libya. A cross-section of the stratigraphy, running from the SW to the NE, extending from the Ajdabiya and Ash Shulaydimah faults into the Cyrenaica basin is presented. This diagram shows the Devonian to Miocene formations, the significant structural features and also the well correlations (C1-2 to A1-41). In this area there are observed a reduced burial and variations in thickness of the crust that is controlled by faults, compared to surrounding troughs on the Cyrenaica Platform.

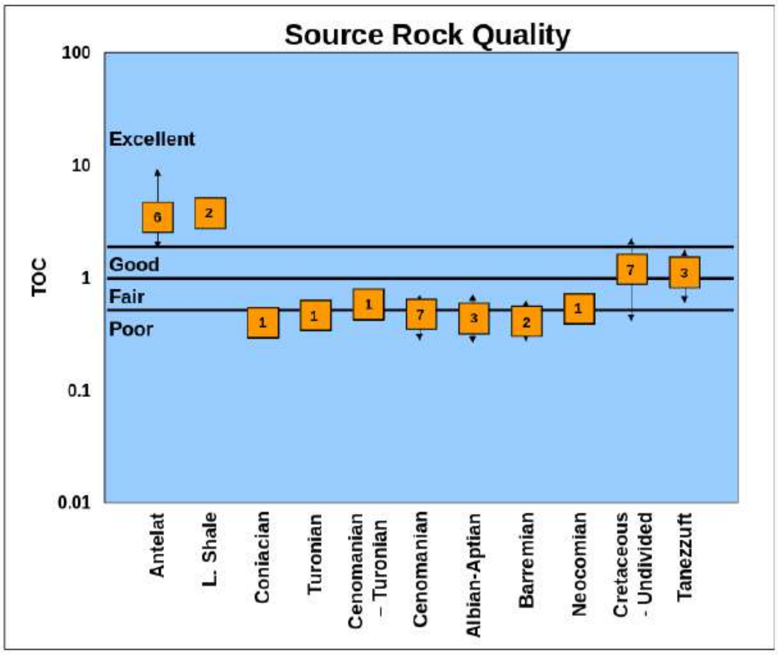

Figure 4. Qualitative source-rock quality ranking for the Cyrenaica. These levels of completeness are often expressed as Poor, Fair, Good, or Excellent. Individual data points are represented by orange squares which have the sample sizes for each group noted within them.

In classifications where a class has adjacent classes with a TOC very close to the class boundary, the classification may be uncertain or variable and is often shown by an arrow on the classification.

Table 1. Summary of representative Rock-Eval characteristics

Interval	TOC (wt%)	HI (mg HC/g TOC)	Kerogen Type	Source Rock Quality
Silurian	1–4+	200–400	II/III	Moderate, gas–oil prone
Lower Cretaceous	0.3–1.5	55–183	II/III–III	Marginal, gas prone
Upper Cretaceous	0.5–3	200–400	II	Moderate, oil prone
Paleogene (Eocene)	1.8–8.7	700–970	I/II	Excellent but localized

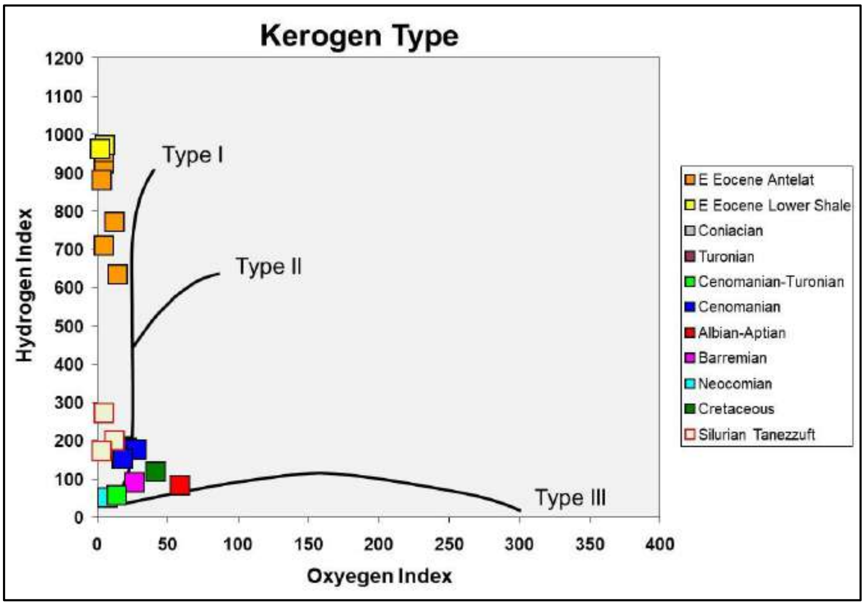

Figure 5. Hydrogen Index (HI) versus Oxygen Index (OI) diagram showing kerogen type classification (Types I, II and III) for source rock samples from northeastern Libya. Symbols are colour-coded by stratigraphic interval, highlighting predominantly mixed Type II/III kerogen in Silurian and Cretaceous successions and locally developed Type I kerogen within Paleogene depocentres.

Silurian source rocks

Silurian organic-rich shales form part of the regionally extensive North African 'hot shale' system, which represents one of the most prolific Paleozoic source rock intervals in North

Africa (Meinhold et al., 2013; Wang et al., 2019). In NE Libya, Silurian shales are rich in organic material where they are preserved, with the total organic content often greater than 1% by weight and usually ranging from 1 to 4% by weight, locally higher in some areas. The S2/S3 ratios point to a mixed kerogen, which is of Type II and III. These types of kerogen were produced from both marine and continental material. This kind of kerogen is typical for North African Silurian 'hot shales'.

The calibration point is the Devonian sandstone gas show in borehole B1-2. The most likely explanation is charging by underlying Silurian shales, because of their position in the section and because there is no younger Paleozoic source rock in the area. Even though there are no commercial discoveries, this suggests that kitchens, migration routes, and/or traps were not adequate to deliver and retain the charging, but is supportive of the in situ generation and migration of hydrocarbons.

The burial history and the one-dimensional basin modelling for well B1-2 shows that this well experienced a subsidence process starting from the Paleozoic era through to the Mesozoic era. This source rock in the Palaeozoic era started to generate oil in the late Cretaceous period and reached its peak generation in the Tertiary period (Figure 6). This timing is consistent with observed gas shows and supports a localised Paleozoic source charge model.

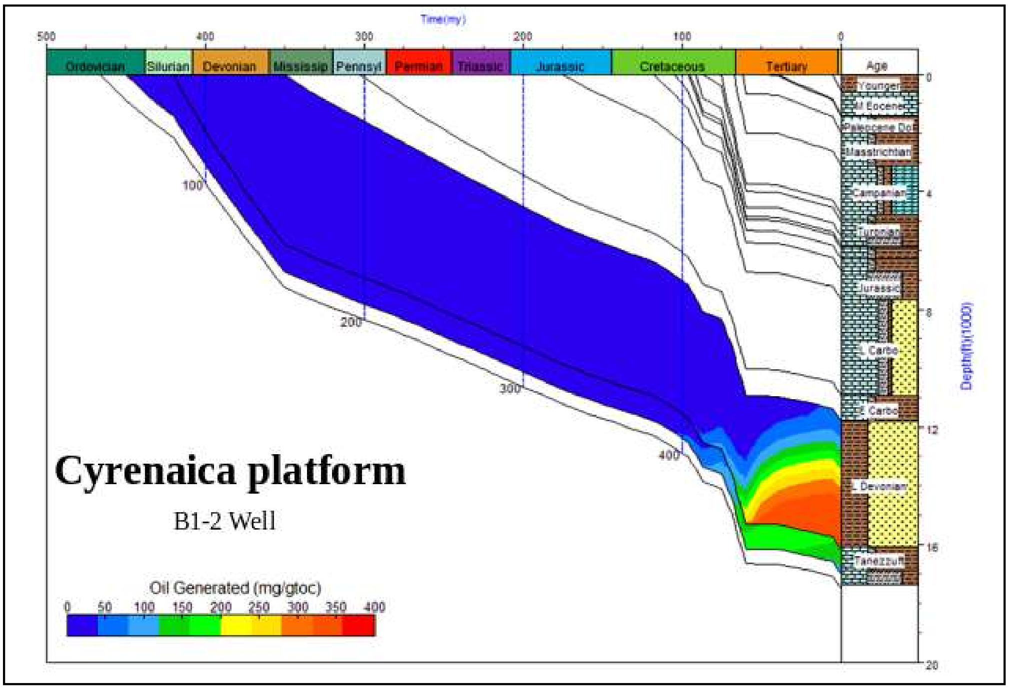

Figure 6. Burial and thermal maturity model for the Cyrenaica Platform showing palaeo-isotherms, burial history, and cumulative oil generation (mg/g TOC) from the Ordovician to the Tertiary. Hydrocarbon generation began in the late Mesozoic with increased burial, while peak generation was restricted to deeper Paleozoic intervals, indicating limited and localized source-rock maturation.

Jurassic–Lower Cretaceous source rocks

Potential for source rock in Jurassic to Lower Cretaceous in the Cyrenaica Platform is typically uncertain and inferred from similar formations, which are carbonate platforms. Such platforms have in their centre Type II to II/III kerogen. Jurassic to Lower Cretaceous source rock, , which is a significant contributor to oil generationin the Sirt Basin, is thin and not buried deeply in Cyrenaica. Thus it cannot contribute much to Libya's north east's oil production (Ahlbrandt, 2001).

In northern Cyrenaica, sedimentary thickness increases with shallow marine carbonates and clayey sediments prevailing, in contrast to the more southern region where continental facies are thinner. The generally low Total Organic Content, and the mixed type II and type III kerogen, can be explained by the dilution and mixing of marine and terrestrial organic matter, found in the Rock-Eval data. This is due to organic rich marine source rocks being spatially restricted, and often diluted by siliciclastic input

Cretaceous source rocks

The TOC content of the analysed samples was in the range of 0.57 to 2.17 % by weight, and the average TOC content was 1.19 % by weight. The H/C weight ratios for the TOC found in the samples lay in the range from 55 to 183 mg HC/g of TOC. This kerogen is classified as Type II and III, characterised by HI and TOC values. This mixed kerogen type is known to produce a low yield of oil. The Tmax values (429–448 °C) indicate variable thermal maturity but do not explain the low hydrogen content of the kerogen. Cyrenaica's probable source rock for oil is an Upper Cretaceous period marine shale. Drilling and exploration in this area have yet to demonstrate the presence of commercially viable oil. Hydrocarbon-bearing strata are limited due to rapid, structurally restricted maturation during the Cenozoic. The formations were breached as a result of the reactivation of inversion related faults after the charge had accumulated (Bosworth, 2017).

Located off Benghazi, the well in question, known as A1-NC-120, was searched for the presence of commercially exploitable oil and natural gas. The oil is believed to have originated from marine Cretaceous deposits. These are thought to date back to the early Cretaceous period. This conclusion is drawn from the study of rock strata and a comparison with similar strata in regions where oil has been discovered. The findings suggest that it is unlikely that there have been commercial hydrocarbon accumulations in the region. This may be due to the hydrocarbons having been in small quantities or formed in areas that have not yet reached an optimum state of maturity.

Paleogene source rocks

Among the intervals studied, the Paleogene succession contains the highest-quality oil-prone source rocks. Libyan oil prone kerogen, as indicated by the Eocene rock evaluations, is plentiful in Libya's north east. The hydrogen content in the oil prone kerogen in Eocene rock from this area is high. Seven samples of Eocene age from wells D1-41, C1-41 and H1-41, had a mean total organic carbon content of 3.74 weight percent. This organic carbon varied from 1.86 to 8.74 weight percent. The TOC levels in these formations are notably higher than those in older rock layers and fall into the category of very good to excellent quality source rocks.

These additional pyrolysis data lend further support to this idea. The S2 values range between 13.2 and 80.65 mg HC/g of rock with a mean of 33.9 mg HC/g of rock, showing a high ability of the source rock to generate hydrocarbons. The maximum temperature for pyrolysis of the Paleogene samples is generally found to be between 425 and 436 degrees Celsius. This places the majority of the samples in an immature to early mature stage of thermal evolution. Most Paleogene samples lie in the immature to early oil-window stage; despite high TOC and HI, limited burial has restricted effective hydrocarbon generation and expulsion. Although the organic matter is of high quality, limited burial depth has restricted effective hydrocarbon generation and expulsion.

Almost all the samples, with the exception of one, grouped together in Tmax values of approximately 420 to 445 degrees Celsius. This temperature range corresponds to Hydrogen Index (HI) values of up to 300 mg HC/g TOC, indicating moderate oil-prone kerogen. One sample from well T1-41 shows a very high HI (~900 mg HC/g TOC) at a relatively low Tmax value. The presence of Type I to II kerogen in the sample indicates that organic matter which will generate oil is present. This hydrogen-rich organic material was deposited in restricted, anoxic marine conditions. The low maturity of these samples implies that oil expulsion efficiency and the extent of expulsion could be limited.

Studies of source rock type, distribution, and organic richness indicate that the most prospective source rocks typically contain more than 2 wt% TOC (Tissot and Welte, 1984). In the majority of the Paleogene samples, the S2 and TOC values for regional thermal maturity are moderate to low. The T1-41 samples show a significantly higher Total Organic Carbon (TOC) content compared to the T1-40 samples. High quality source rock is known to exist in these regions, but only in areas such as certain structural traps or individual wells. This suggests that small kitchen areas were scattered throughout the region in the Paleogene era, rather than a continuous large supply system existing.

A scatter plot in Figure 7, reveals uneven patterns when linking the hydrogen index (HI) to Tmax. Rather than forming a tight cluster, data points are dispersed across Tmax values between 420 and 445 °C. For the most part, Paleogene samples sit within this range, often showing TOC-based generative capacity at or below 300 milligrams per gram. These characteristics indicate an immature thermal state with limited oil-generation potential. One stand-out case is well T1-41, showing very high HI values - above 900 - alongside moderate Tmax levels. This points to sections packed with oil-forming organic material that still sit within early stages of heating, such intervals are spatially restricted. When looking across the Paleogene period, the consistency of source rock traits drops sharply. Instead of broad patterns, small-scale geological details seem to shape the characteristics more. So, while some areas hold promising material, there's no sign of extensive, mature intervals spread across the region.

Across the region, levels of total organic carbon (TOC) and S2 suggest only slight to moderate organic presence, as shown in Figure 8. Many samples report TOC close to 1.5 percent by weight, alongside S2 readings near 5 milligrams hydrocarbon per gram of rock. Notably, well T1-41 still stands out - this location holds better thermal maturity and stronger formation potential. Yet such traits appear at best in scattered spots, far from widespread. The distribution of the data does not support the presence of laterally extensive, effective source kitchens capable of charging large hydrocarbon accumulations. Still, past research backs up the view that even though Paleogene layers show good promise in spots, they do not stretch wide enough to build large oil or gas reserves across entire areas. Burial depth does not obviously influence organic levels (Figure 9). At matching depths, total organic carbon spreads out in uneven patterns. Deeper burial does not reliably boost TOC values. Conditions during deposition seem to matter more than how long matter has been subsided. Sediment thickness in the local area at low to mid-level depths does not always match higher total organic carbon levels - even deeper sections show similar peaks. What mainly shapes where organic material accumulates is the type of deposit it forms in.

Even though local conditions favor hydrocarbon formation, Paleogene source rocks rarely produce significant amounts because they are too sparse and not deeply buried enough. During the Early Eocene, certain basins saw elevated terrain form through late Tertiary movement above the earth's surface - this halted heat-driven transformation, meaning less oil and gas were created. As a result, any oil or gas made here probably flowed into tiny, isolated pools instead of large, economic ones.

Together, data from Figures 7, 8, and 9 show the Paleogene in northeastern Libya holds limited hydrocarbon chance - found only in isolated spots. Near the upper part of rich organic layers, rock types favorable for oil and gas exist. Still, these sections break apart laterally, spread too thin to clearly map playable areas. Their ability to generate useful reserves has shrunk because folding and weathering have stripped away thickness over time.

Given these circumstances, hydrocarbon migration would be anticipated to occur over relatively short distances, with likely small, patchy oil or gas fields.

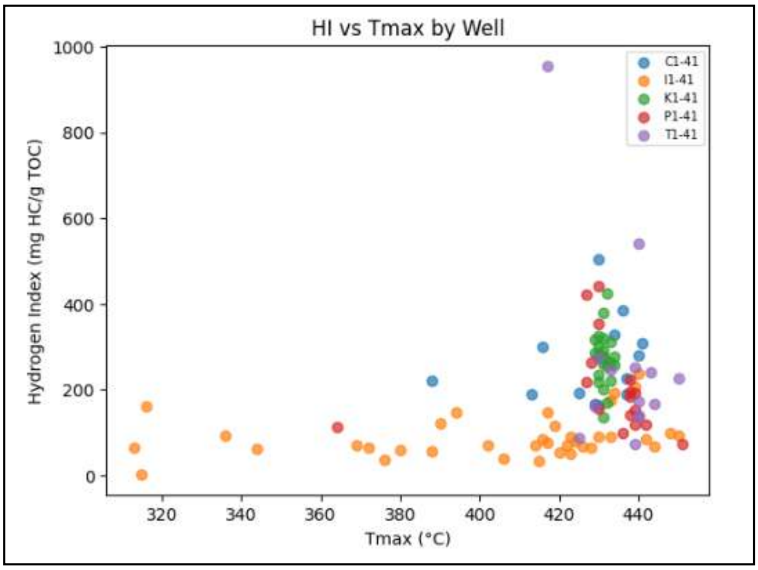

Figure 7. Plots of the hydrogen index versus maximum temperature show that most samples cluster at approximately 420-445 degrees Celsius, with HI below 300 milligrams of hydrogen carbonate per gram of total organic content. This well T1-41 shows a HI of greater than 900 at relatively low Tmax values; this suggests that it is associated with immature oil-prone facies, which are confined in their distribution, and there is no evidence of a mature source rock.

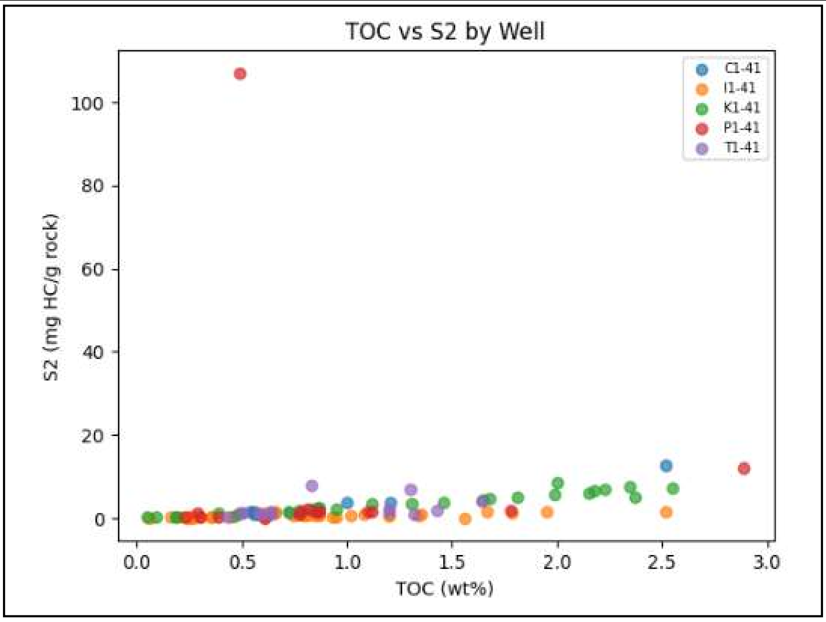

Figure 8. The TOC and S2 levels in this area are generally low to moderate with 1.5 weight percent TOC and 5 milligrams Hc per gram rock for S2. The moderate to high thermal regimes found at T1-41 are typical for wells with good quality source rocks, which in turn may contain good source rocks in a localised rather than widespread area.

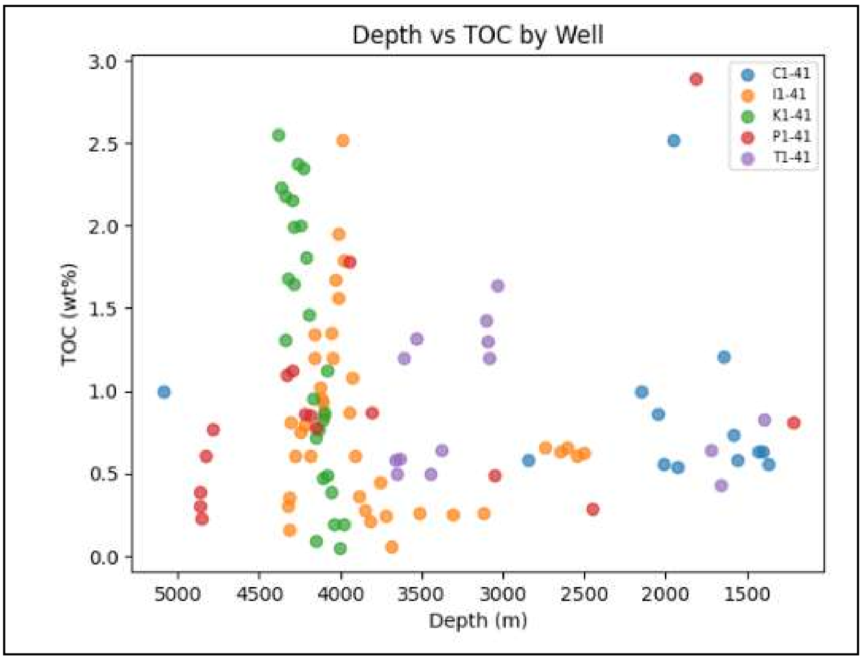

Figure 9. Depth versus TOC by well. It is observed that TOC versus depth plots for individual wells do not show a systematic increase in organic carbon with burial depth, suggesting organic carbon is controlled by depositional facies and not by the depth of burial. Local increase in the thickness of the geological layers is observed at the depths ranging from shallow to intermediate, whereas a significant amount of organic material is found at the deeper parts.

Discussion

The Libyan east region's poor exploration success is due to a complex interplay of several factors, rather than the characteristics of the source rocks. Exploration efforts have been limited due to the small volume of economically recoverable hydrocarbons. The potential source rocks of the Silurian period through to the Paleogene period have a number of favourable characteristics. Hydrocarbon generation potential in the area is strongly controlled by structural configuration and burial history; however, source rock distribution remains highly discontinuous.

The Paleogene period source rock reservoirs found in the area in question are highly likely to be petroleum bearing. These rocks were comprised of substantial organic material and had a low hydrogen to carbon ratio. Because of their distribution, these rocks may act as a source for hydrocarbons, however, this role is limited due to their low maturity. Their geographical distribution also prevents them from having a bigger contribution. In the Paleogene era, deposits which had brief periods of burial were located in small depressions. These were uplifted during the Neogene, having been subjected to only brief periods of burial. Hydrocarbon generation was confined to small, isolated depocentres due to limited maturation and short residence times within the oil window. Due to its short operational time, the system's ability to fill traps and larger or more remote ones would be severely limited (Bosworth, 2017).

The Cretaceous and Lower Eocene marine shales in the region are inferred to be highly productive from regional stratigraphy and the REVAL analysis. Data suggests that in this area, oil reached maturity only in a few places and this was over a very short period. In the A1-NC120 well, situated offshore Benghazi, hydrocarbon generation from the local Cretaceous source rocks is shown to be limited. Studies conducted at this site show the source rocks have generated oil. The hydrocarbon charge may either not have been preserved or may not have been sustained. The generally poor to moderate evaluations of the Mesozoic intervals within Cyrenaica, shown in figure 4, indicate the low quality of the source rock in that area.

This Devonian sandstone gas show in well B1-2 serves as a crucial calibration point for activity within Paleozoic petroleum systems. The most likely source of the oil is Silurian age shale. This suggests that the Silurian age was capable of producing oil. Commercial success is unlikely to be achieved through generation alone. The presence of hydrocarbon shows indicates that generation has occurred; the limiting factor is likely efficiency in migration, trap formation, or seal integrity.

The thermal maturity pattern across the Cyrenaica Platform and Al Jabal al Akhdar region supports a petroleum system limited by the extent and productivity of its source kitchens. Given the influence of Neogene uplift and erosion, it follows that potential source intervals experienced brief periods of residence within the oil or gas window. Here, it may be that uplift took place after the initial production of oil and gas, thus the likelihood of oil or gas escaping from traps is greater.

The effectiveness and distribution of reservoir traps are governed by structural compartmentalization within the reservoir. At the start of a petroleum province's history, movement in the Earth's crust may have helped oil and gas reach the surface. Subsequent movements could lead to hydrocarbon seepage. The movement of laterals across the area is hampered by structural segmentation. The region in Cyrenaica is different, in that it is characterized by petroleum systems which are not extensive, unlike those in the Sirte Basin. These systems charge only short distances from small, localized petroleum source rocks. In contrast, Cyrenaica is marked by smaller, disjointed hydrocarbon systems which are inherently less efficient in terms of charge than the large, laterally extending systems in the Sirte Basin.

In the northeastern region of Libya, charge effectiveness is largely governed by meagre volumes of effective kitchens, a heterogeneous and intermittent thermal maturity, and the tectonic disturbances that follow a charge. It seems more logical to interpret non-commercial and isolated hydrocarbon shows as being indicative of local oil and gas systems rather than widespread oil migration.

Table 1. Summary of Burial History and Maturity Constraints from NE Libya Wells

Well	Stratigraphic Coverage	Burial / Maturity Character	Petroleum System Implication
B1-2	Silurian–Devonian	Moderate burial; limited maturity	Localized Silurian-sourced gas show
E1-2	Jurassic–Cretaceous	Deeper Late Cretaceous burial	Short-lived maturity, limited expulsion
B1-NC152	Jurassic–Cretaceous	Relatively deep burial	Potential kitchens but discontinuous
D1-41	Cretaceous–Paleogene	Localized deeper depocenter	Restricted Paleogene kitchen
A1-NC120	Jurassic–Cretaceous	Shallow burial	Non-commercial Cretaceous charge
A1-18	Jurassic–Cretaceous	Very shallow burial	Immature source intervals

Conclusions

The stratigraphic succession in northern Libya exhibits diverse geochemical signatures. The Rock-Eval geochemical plots for the various blocks show a continuous trend from the Silurian to the Palaeogene. The absence of commercial oil production in the area suggests that while source rocks are present, their hydrocarbon generation capacity is low. Although the Eocene source rocks are of good geochemical quality, their limited areal extent and insufficient burial have restricted thermal maturity and therefore limited oil generation. In several exploration wells Jurassic and Cretaceous source rocks are found to be sparse. This suggests that regionally extensive and effective source rocks for commercial oil and gas accumulations are absent or insufficiently mature in the area. The presence of a gas show in a well labelled B1-2 suggests that a Silurian source in the area may still exist undiscovered or may be underdeveloped. Future exploration should focus on structurally undisturbed zones that may have retained hydrocarbons bypassed during early migration phases.

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Reassessment of Source Rock Potential and Charge Effectiveness in the Cyrenaica, NE Libya

إعادة تقييم إمكانات الصخور المصدرية وفعالية الشحنة الهيدروكربونية في إقليم برقة شمال شرق ليبيا

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الملخص

في هذه المقالة، تتم مراجعة إمكانات الصخور المصدرية في المناطق الحاملة للنفط في الأجزاء الشمالية الشرقية من ليبيا. وتشمل المناطق التي تم تناولها بالدراسة منصة برقة، وحوض عش شليديمة، ومنطقة الجبل الأخضر. وقد استُخدمت البيانات الجيوكيميائية الإقليمية لتحليل روك–إيفال بالاقتران مع بيانات روك–إيفال المعتمدة على الآبار، إضافة إلى نتائج آبار الاستكشاف، لتوفير معلومات حول توزيع وجودة الصخور المصدرية المحتملة من العصر السيلوري إلى العصر الباليوجيني.

تُظهر الصخور المصدرية من العصرين الباليوسيني والإيوسيني جودة ممتازة محليًا، حيث تتراوح قيم مؤشر الهيدروجين بين 700 و970 ملغم هيدروكربونات لكل غرام من الكربون العضوي الكلي، وتبلغ نسبة الكربون العضوي الكلي تقريبًا بين 1.9 و8.7 بالمئة بالوزن. وبوجه عام، تُظهر صخور العصر الطباشيري جودة مصدرية متوسطة، مع مستويات كربون عضوي كلي تتراوح بين 0.6 و2.2 بالمئة بالوزن، وقيم مؤشر هيدروجين تتراوح بين 55 و183 ملغم هيدروكربونات لكل غرام من الكربون العضوي الكلي.

وقد تم تأكيد توليد الهيدروكربونات محليًا من خلال بيانات الآبار، بما في ذلك ظهور غاز في حجر رملي من العصر الديفوني يُعتقد أنه ناتج عن صخور طفلية سيلورية تقع أسفله. ومع ذلك، لم يتم حتى الآن تسجيل أي اكتشافات تجارية. وتُظهر أنماط النضج الحراري للصخور في المنطقة تباينًا كبيرًا نتيجة لتعدد فترات الدفن القصيرة، إضافة إلى تعرض المنطقة لعمليات رفع تكتوني بعد ترسيب هذه الصخور، ويظهر ذلك بشكل خاص في منطقتي الجبل الأخضر وحوض عش شليديمة. أما في إقليم برقة، فيبدو أن العامل المحدِّد لفعالية النظام البترولي هو محدودية حجم مناطق التوليد (المطابخ البترولية)، وتقييد مسافات الهجرة، وضعف الشحنة الهيدروكربونية، وليس غياب الطبقات الغنية بالمادة العضوية.