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Recognization and characterization of sources rocks in well BX in the sedimentary basin of Cote d'Ivoire

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Abstract. In order to recognize and characterize the sources rocks in the BX well, samples of this well have been selected and analysed using Rock-Eval pyrolysis method and another set samples were prepared and observed through microscope for visual kerogen characterisation. The total organic carbon of BX well sediments varies between 0.41 and 3.41 wt%, with 1.29 wt% on average. These high values indicate good organic matter content in this well. The hydrogen index (HI) of the studied samples ranges from 49 to 292 mgHC/g_{TOC}, with an average of 109 mgHC/g_{TOC}, indicating mainly a type III kerogen. This kerogen is composed of humic material (vitrinite and inertinite) and amorphous organic matter with marine microfossils (dinoflagellate cysts and micro-foraminiferal linings). Thermal maturity parameters show that, Maastrichtian, Campanian, Early Senonian and Turonian are immature with T_{max} values below 435 °C. However, according to T_{max} values, samples reach oil window in Albian at 9840 ft while spore colour index indicate that this limit can be put at 9210 ft into Cenomanian age. The section from 7260 to 7590 ft in Campanian interval displays the best qualities of source rock. This section is composed of good quantity of type III and type II/III kerogen with moderate hydrocarbon potential, but this source rock is immature to generate hydrocarbons.

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Распознавание и характеристика исходных пород в скважине ВХ в осадочном бассейне Кот-д'Ивуара

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Аннотация. Отобраны и проанализированы методом пиролиза Rock-Eval образцы из скважины ВХ, для того чтобы определить и охарактеризовать исходные породы в ней. Другой набор образцов подготовлен и просмотрен с помощью микроскопа для визуальной характеристики керо-

Ключевые слова:
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гена. Общее содержание органического углерода в отложениях скважины BX варьируется от 0,41 до 3,41 весовых %, в среднем 1,29 весовых %. Такие высокие значения указывают на хорошее содержание органического вещества в этой скважине. Водородный индекс (HI) исследованных образцов колеблется от 49 до 292 мгHC/гTOC, в среднем 109 мгHC/гTOC, что указывает на наличие в основном керогена типа III. Этот кероген состоит из гуминового материала (витринита и инертинита) и аморфного органического вещества с морскими микрофоссилиями (цисты динофлагеллят и микрофораминиферовые отложения). Параметры термической зрелости показывают, что Маастрихтский, Кампанский, ранний Сенонский и Туронский периоды являются незрелыми со значениями T_{max} ниже 435 °C. Однако, согласно значениям T_{max}, образцы достигают нефтяного окна в Альбе на высоте 9840 футов, в то время как индекс цвета спор указывает, что этот предел может быть установлен на высоте 9210 футов в сеноманском возрасте. Участок от 7260 до 7590 футов в кампанском интервале демонстрирует лучшие качества исходной породы. Данный разрез состоит из хорошего количества керогена типа III и типа II/III с умеренным углеводородным потенциалом, но эта исходная порода незрелая для генерации углеводородов.

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Introduction

Geologically, Côte d'Ivoire is characterized by a Precambrian basement, which occupies 97.5% of its total area, and a later sedimentary basin (Lower Cretaceous BC), the incipient part of which occupies 2.5% of the Côte d' Ivoire. The sedimentary basin of the Ivory Coast consists of two main zones: Onshore and Offshore.

This article is based on the results of analysis of rock samples from the BX well, located on the shelf of Côte d'Ivoire. It presents the results of qualitative and quantitative geochemical analysis of 136 samples using Rock-Eval pyrolysis and visual analysis of kerogen. The interpretation is based on published geochemical data and comparative data from previously drilled wells in the Ivoirian Basin.

The purpose of this study is to recognize and characterize source rocks by determining the quantity, quality and maturity of organic matter as defined [1].

1. Results and interpretation

The geochemical log (Figure 1) shows the evolution of each parameter with depth. Well BX shows that:

– the organic matter content of this well is generally good (1 < TOC < 2 wt%);

– samples contain mostly kerogen with poor hydrocarbon potential (S2 < 2.5 mgHC/g_{rock}). Only the interval from 7260 to 7590 feet, in Campana, contains kerogen with good (2.5 < S2 < 5 mgHC/g_{rock}) hydrocarbon potential;

– hydrogen index and oxygen index of the studied samples indicate the predominance of mixed type III kerogens capable of generating gas;

– thermal maturity increases with depth and samples reach the Alba oil window.

The mass content of TOC in this well is usually less than 4% and fluctuates between 0.14 and 2.15% of the mass. Samples with moderate energy source (TOC < 1% mass) make up 44.67% of the total number of samples from the well, while moderate (1 < TOC < 1.5% mass) energy source is 23.33% and good source rocks (TOC > 1.5% mass) make up only 32% of the total samples from the well (Figure 2). These percentages indicate good primary productivity and/or favorable organic matter retention. In the Côte d'Ivoire Basin, studies have shown that significant parent rocks typically have TOCs greater than 1.5% mass, which in this well is represented in 32% of the samples (Figures 2, 3).

Samples from the studied well show a good content of organic carbon in the Turonian (average 0.68 wt%), Cenomanian (average 0.59 wt%) and Albian (average 0.88 wt%) periods. A slight increase in organic matter with a good content of TOC (1 < TOC < 1.5 % mass) is noted in the Early Senonian (average 1.03% mass), Campanian (average 1.30% mass) and Tertiary (average 1.48% mass) periods. The Maastrichtian interval is the richest in organic matter. TOC values range from 1.42 to 2.15 with an average value of 1.71% mass. Source rock characterization is not limited to the amount of recorded organic matter, since TOC is not the only indicator of oil potential, and many rocks with high TOC values may have low oil source potential due to the quality of the kerogen content. Thus, high TOC values are a necessary but not a sufficient criterion for good source stone material (Table 1). The type of organic matter and the potential for hydrocarbon formation must also be taken into account in order to more accurately characterize the source rocks [2].

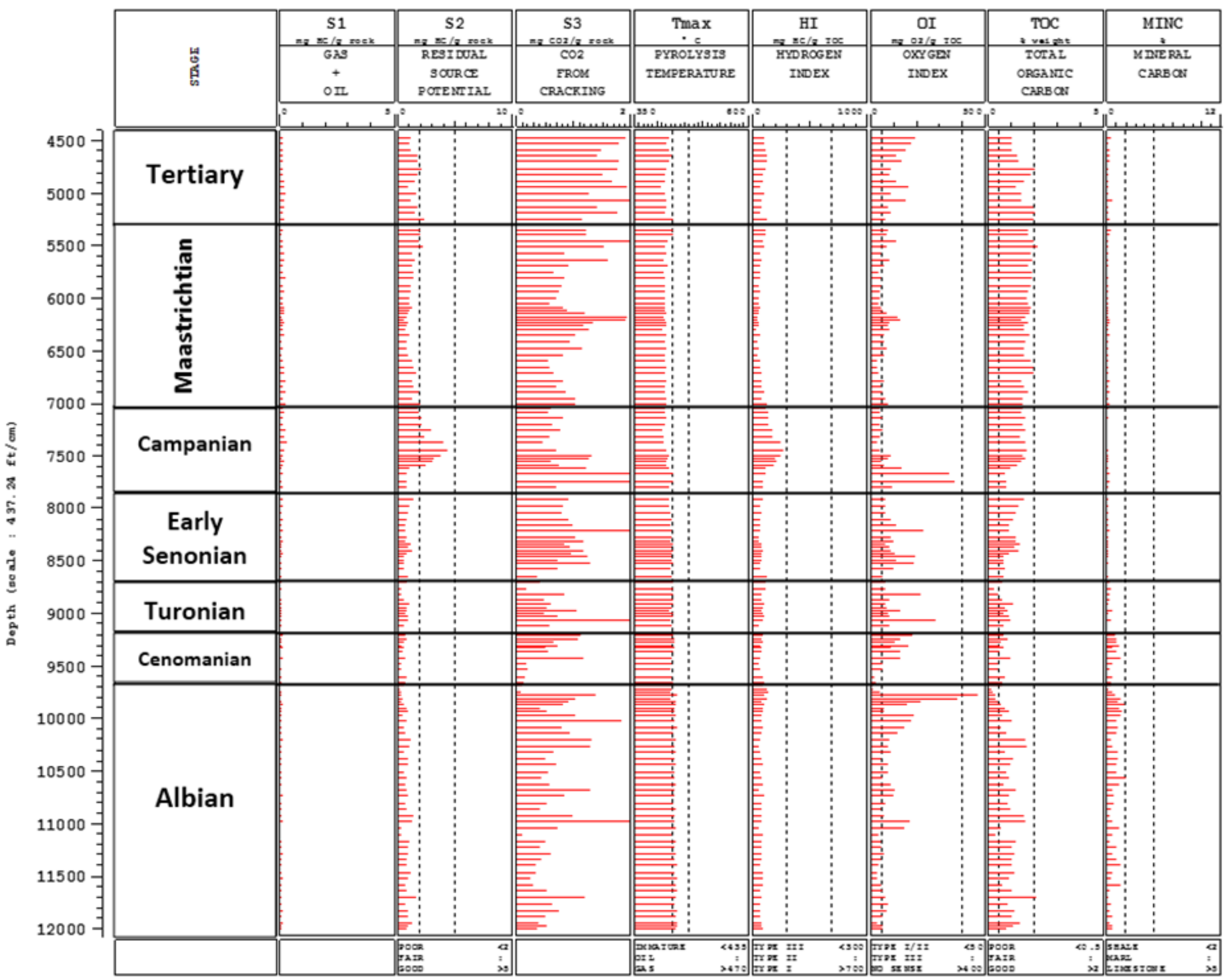

Figure 1. Geochemical log of well BX

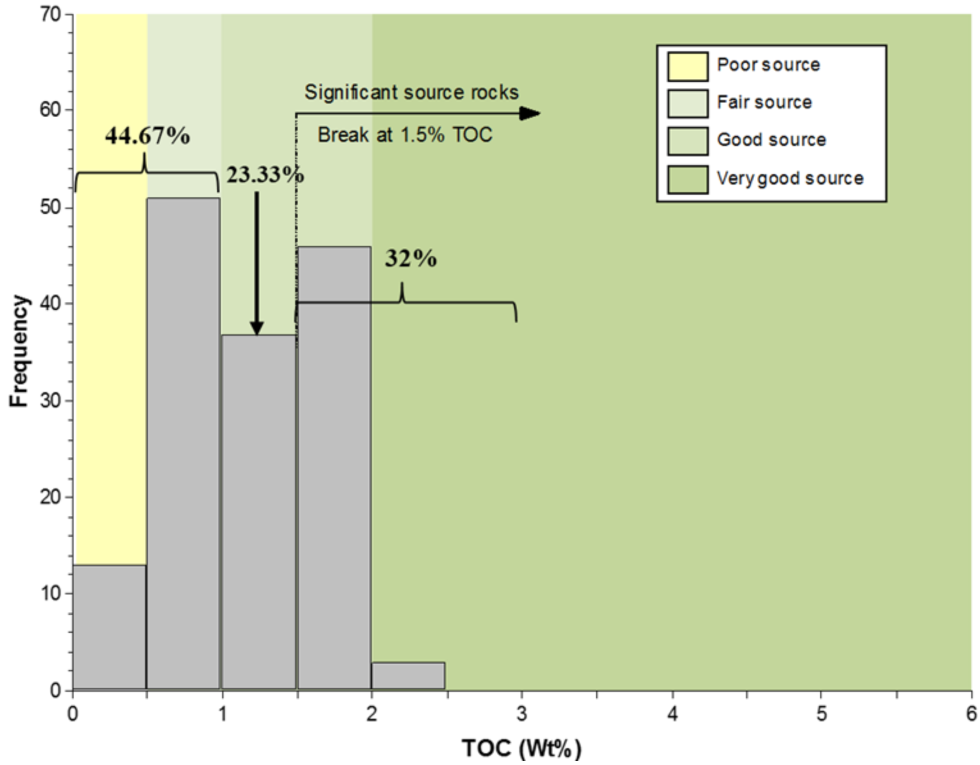

Figure 2. Total organic carbon (TOC) distribution in well BX

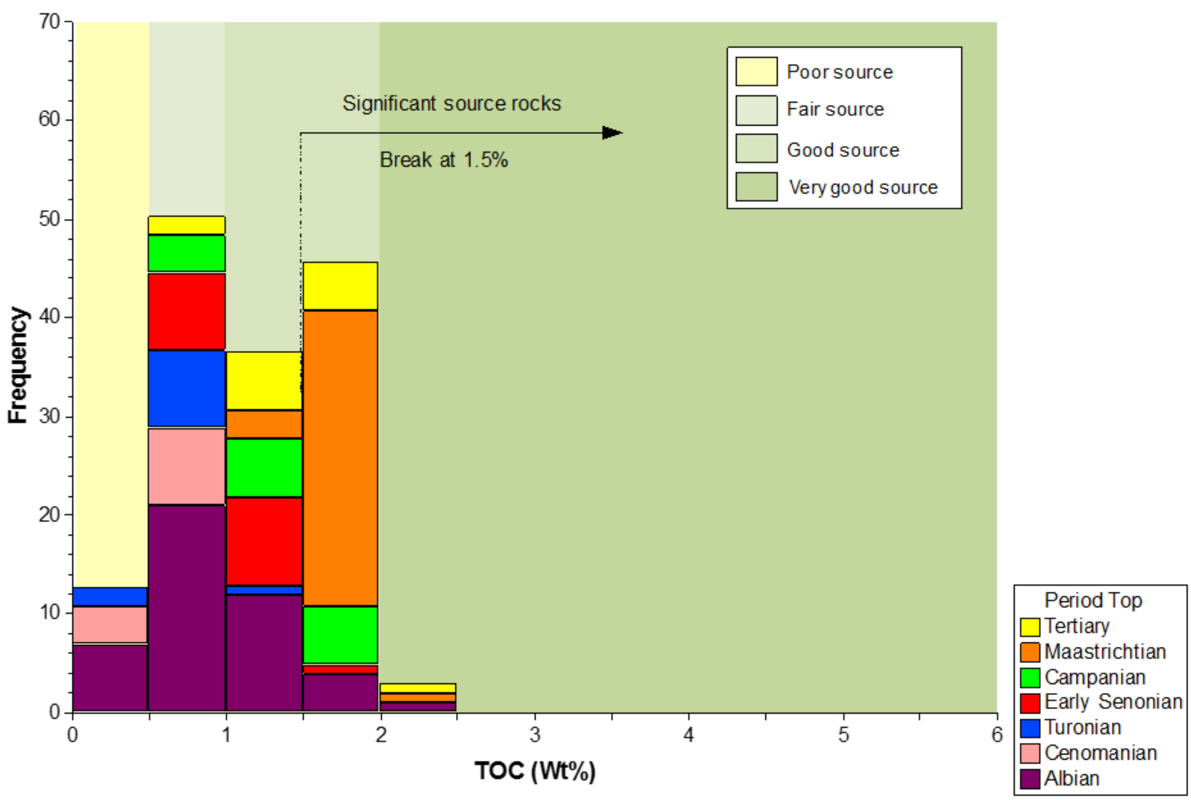

Figure 3. Total distribution of organic carbon (TOC) in well BX across stratigraphic units in color

Table 1

Values of Rock-Eval 6 parameters for the stratigraphic horizons of well BX

Depth, m		S2, $mgHC/g_{rock}$	T_{max}, °C	TOC, % weight	HI, $mgHC/g_{TOC}$
Maastrichtian (5310'–7050')	Min	0,46	413	1,42	32
	Max	2,17	433	2,15	126
	Moy	1,22	418,7	1,72	70
	Nb	34			
Campanian (7050'–7860')	Min	0,68	409	0,64	91
	Max	4,33	434	1,64	264
	Moy	2,26	420	1,31	163
	Nb	16			
Early Senonian (7860'–8700')	Min	0,5	425	0,66	49
	Max	1,38	435	1,51	118
	Moy	0,81	430	1	77,8
	Nb	18			
Turonian (8700'–9180')	Min	0,3	439	0,27	63
	Max	1,06	435	1,02	112
	Moy	0,62	432	0,68	90,6
	Nb	11			
Senomanian (9180'–9690')	Min	0,23	432	0,37	61
	Max	0,68	440	0,82	102
	Moy	0,49	433	0,6	80,67
	Nb	12			
Albian (9690'–12 000')	Min	0,24	430	0,14	56
	Max	1,52	440	1,66	137
	Moy	0,7	438	0,88	83
	Nb	45			

2. Type of organic matter

The type of organic matter and oil potential are an important factor in the evaluation of potential rocks and have a significant impact on the nature of the hydrocarbons formed [1; 3; 4].

Hydrogen index (HI) values range from 32 to 264 $mgHC/g_{TOC}$ in the BX well, which is mainly composed of type III kerogen (Figure 4). The composition of organic matter in sediments and sedimentary rocks reflects the vast number of variables that affect the terrestrial or aquatic environment in which it is formed, its transport to the site of deposition, and its change after deposition [5]. Thus, the type of kerogen is classified on the basis of organic geochemical and optical properties. Different types of kerogen produce different types of hydrocarbons. In general, type I kerogen (HI > 600 mg and type II (300 < HI < 600 mg), usually obtained from lacustrine and marine rocks, is the best kerogen and is capable of generating liquid hydrocarbons [6]. Type III kerogens (50 < HI < 200 mg), which mainly consist of woody materials, are gas-permeable [7; 8].

From a practical point of view, the IH–IO diagram can locate different types of organic matter in their characteristic areas of origin. Organic material is usually in type III, which indicates the gas content of the source.

According to a petrographic study in transmitted and ultraviolet light, kerogen contains mainly amorphous organic matter, which is found in abundance in the Maastrichtian, Campanian, Turonian stages and in the upper part of the lower Senonian stage. Wood organic matter consists mainly of terrestrial-derived structure in the form of degraded phytoclasts (vitrinite) and was found in abundance in the lower part of the Lower Senonian, Cenomanian and Albian. Inertinitis is also present locally in small amounts (0 to 15%). Fluorescence is the ability of organic compounds to produce luminescence (visible light) when irradiated with blue light and UV excitation. Organic compounds that have good fluorescent properties are interpreted as rich in hydrogen (high lipid content), rocks with a low hydrogen content are characterized by little or no fluorescence. The Fluorescence Preservation Index (FPI) characterizes the fluorescence intensity of an amorphous matrix compared to a palynomorphic matrix and is important for both maturity and kerogen composition. FPI [9] defines 5 categories that correlate with hydrogen pyrolysis indices of immature samples. Under fluorescent light, the fluorescence retention index (FPI) of this kerogen shows average retention (FPI between 2 and 4) for hydrocarbon generation (Figures 5, 6).

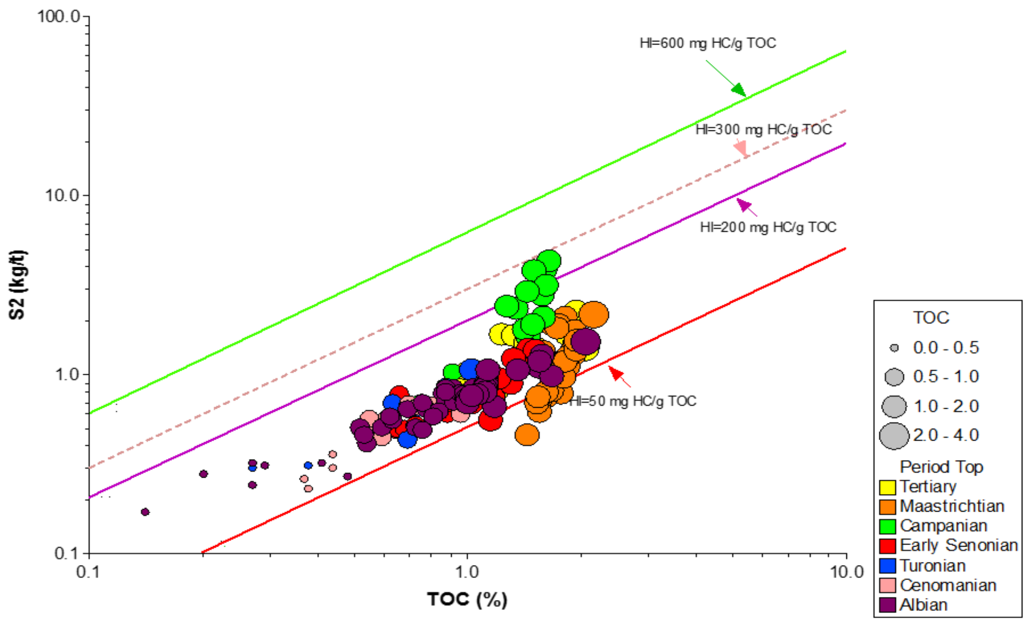

Figure 4. Change in S2 Rock-Eval as a function of total organic carbon (TOC) of well BX in logarithmic coordinates and in color

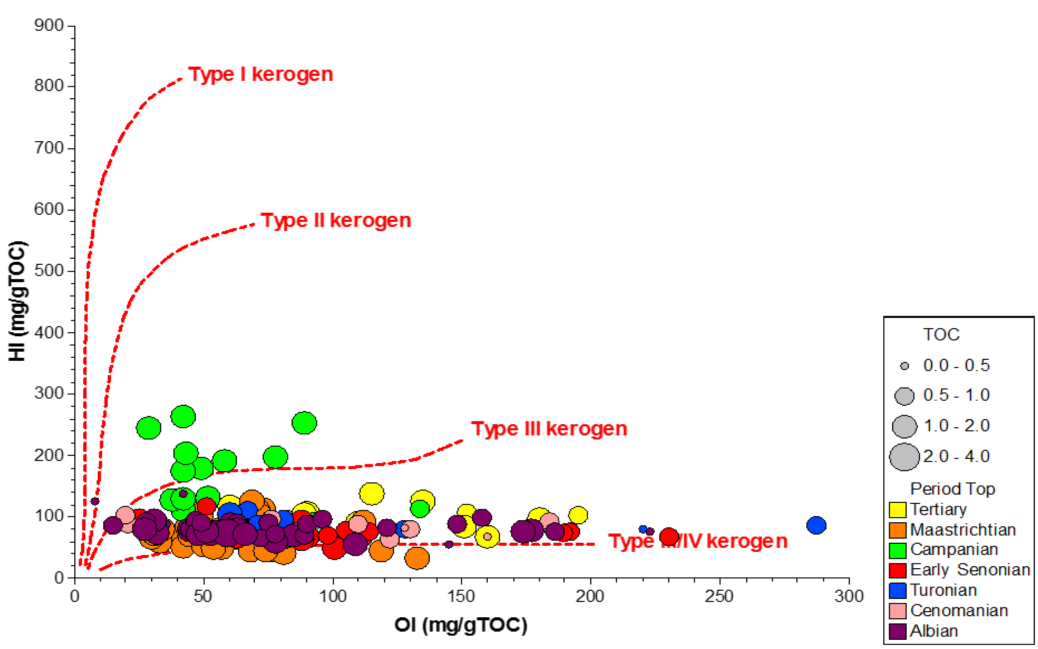

Figure 5. HI–OI plot of well BX with stratigraphic coloured references

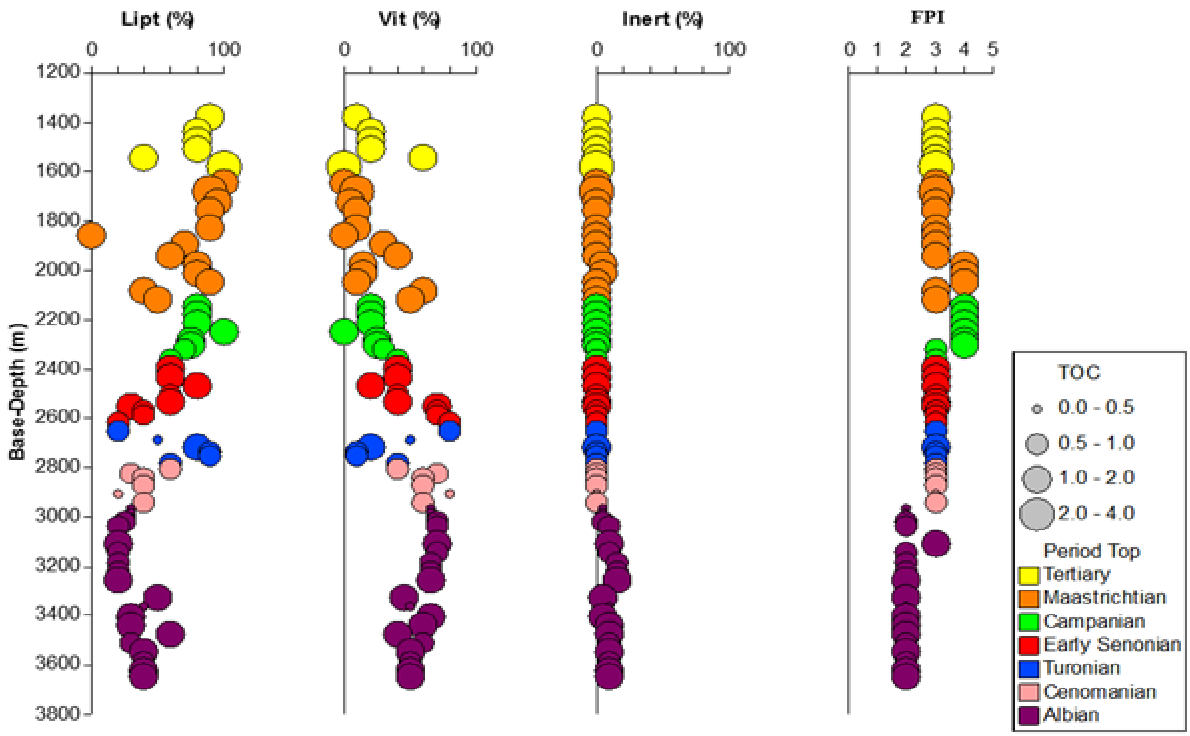

Figure 6. Screening of source rock kerogen depending on the depth of the BX with stratigraphic coloured references

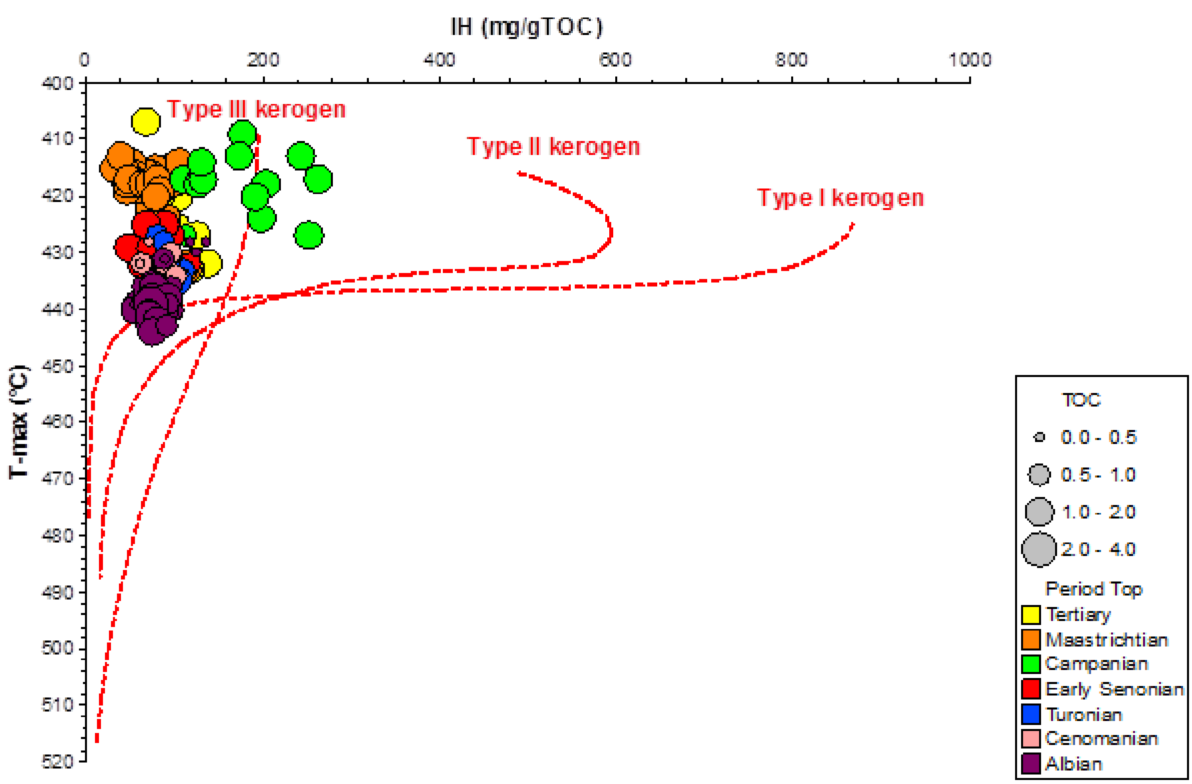

Figure 7. Change in the hydrogen index in accordance with the T_{max} of the assessment of the rocks of the well BX with stratigraphic coloured references

A clearer idea of the type of kerogen is presented in Figure 7, which takes into account the influence of kerogen maturity (y-axis = T_{max}) depending on the hydrogen index. This graph clearly shows a cloud of points belonging to pure type kerogens and mixed type III, prone to gas formation. T_{max} values usually indicate immature organic matter.

3. Oil potential

Oil potential measures the ability of kerogen to generate hydrocarbons at maturity. In the BX well, the oil potential (S2) ranges from 0.63 to 4.78 mgHC/g_{rock} in the studied samples. Such low values (average S2 = 1.36 mgHC/g_{rock}) are indicative of a weak or good oil potential of kerogen. Figure 8 shows the change in S2 with depth.

Figure 6 shows that in the Tertiary, Maastrichtian, early Cenonian, Turonian, Cenomanian, and Albian intervals, S2 values are less than 2.5 mgHC/g_{rock}, indicating a low oil potential in these ages, which cannot be considered as source rocks. Only the 7260 to 7590 ft interval at Kamapan has good oil potential with S2 values between 2.5 and 5 mgHC/g_{rock}. This interval contains parent rock that can generate sufficient hydrocarbons when it reaches maturity.

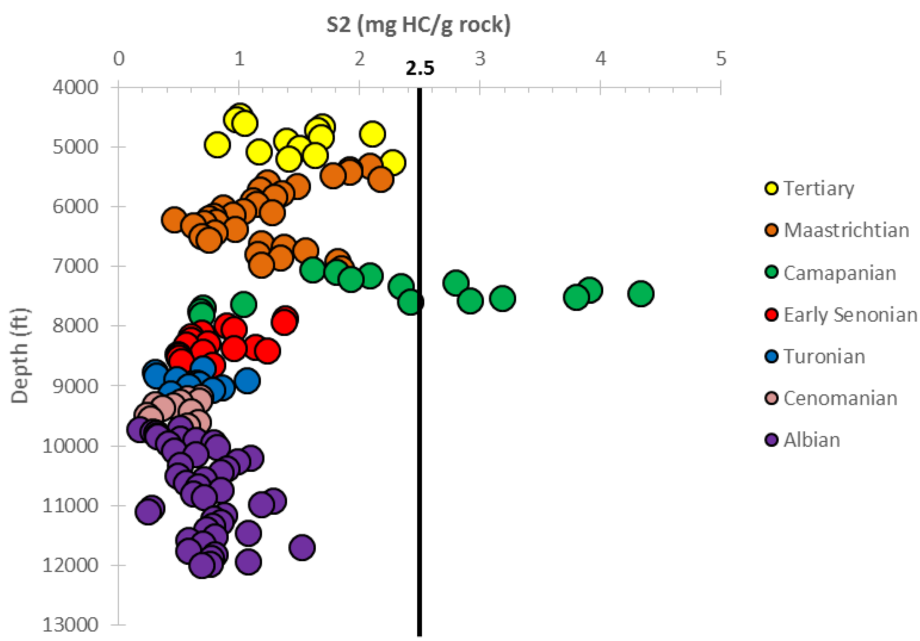

Figure 8. Diagram of dependence of S2 on the depth of the well BX

4. Thermal maturation

The thermal maturation parameters used to assess the degree of organic maturity in this study are T_{max} and SCI data [10; 11].

The T_{max} value, which indicates the maturity of the parent rock, increases with depth [5]. However, faults, folding, dips, geothermal gradients, migrating oil, sample quality, amount of organic matter, mineral matrix in the rock, and analysis errors can lead to differences in obtaining accurate T_{max} values [12; 13]. Maturity assessment based on T_{max} values generally indicates Tertiary to Cenomanian immaturity of kerogen. The samples reach the oil window in the Albian at a depth of 9840 feet (Figure 9) [14; 15].

The total organic carbon (TOC) in the BX well sediments ranges from 0.41 to 3.41% mass, averaging 1.29% mass. Such high values indicate a good organic matter content in this well. The hydrogen index (HI) of the studied samples ranged from 49 to 292 mgHC/g_{TOC}, with an average of 109 mgHC/g_{TOC}, indicating the presence of mainly type III kerogen. This kerogen consists of humic material (vitrinite and inertinite) and amorphous organic matter with marine microfossils (dinoflagellate cysts and microforaminiferal deposits). The thermal maturity parameters show that the Maastrichtian, Campanian, early Senonian and Turonian periods are immature with T_{max} values below 435 °C. However, according to the T_{max} values, the specimens reach the Albian oil window at 9840 feet, while the spore color index indicates that this limit can be set at 9210 feet, in Cenomanian age. The section from 7260 to 7590 feet, in the Campanian interval, shows the best qualities of the source rock. This section consists of a good amount of Type III and Type II/III kerogen with moderate hydrocarbon potential, but this source rock is immature for hydrocarbon generation (Table 2).

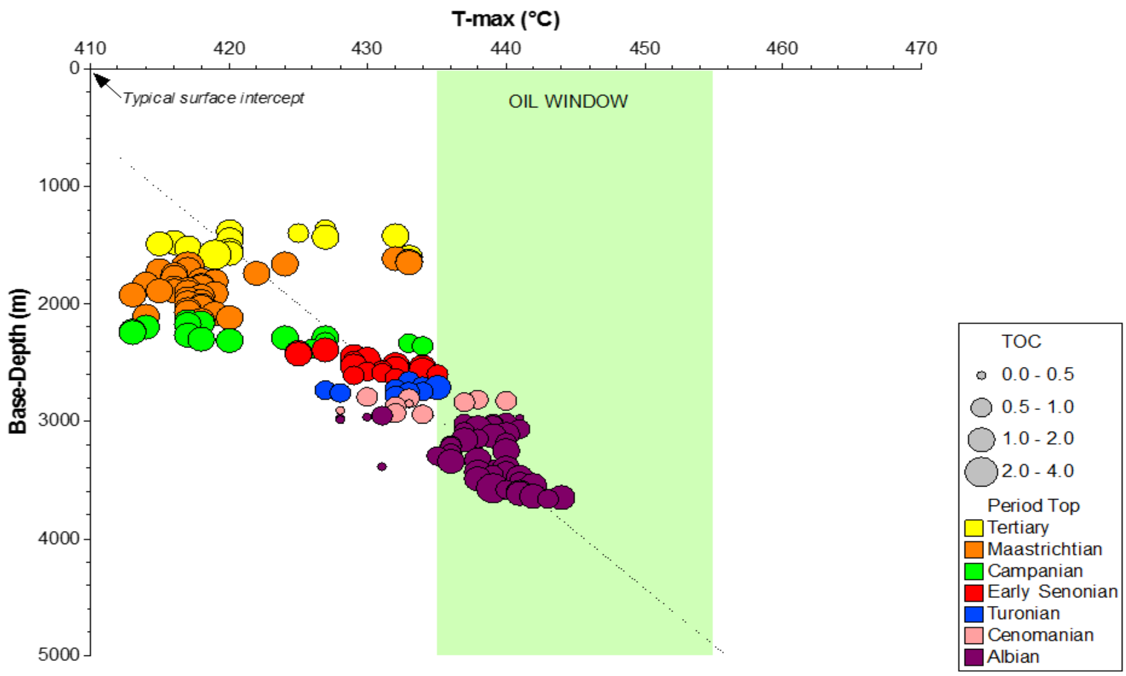

Figure 9. Diagram of T_{max} versus well depth BX with stratigraphic coloured references

Table 2

Summary of Rock-Eval 6 well BX parameters

Age		Hydrocarbon potential	Maturity	Type of mother rock	COT	Note
Maastrichtian	5310–7050'	Low	Immature	Type III	Good	No mother rock
Campanian	7050–7260'	Low	Immature	Type III	Good	No mother rock
	7260–7620'	Average	Immature	Type III/Type II/III	Good	Average value. Mother rocks for gas
	7620–7860'	Low	Immature	Type III	Average	No mother rock
Early Senonian	7860–8430'	Low	Immature	Type III	Good	No mother rock
	8430–8700'	Low	Immature	Type III	Average	No mother rock
Turonian	8700–9180'	Low	Immature	Type III	Average	No mother rock
Senomanian	9180–9690'	Low	Immature	Type III	Average	No mother rock
Albian	9690–12 000'	Low	Early-mature	Type III	Average	No mother rock

Conclusion

Geochemical analysis of samples from well BX allowed us to identify potential source rocks for this well. The 7290–7620' interval in the Campanian demonstrates the best qualities of the oil and gas bearing rock. This source rock contains good amounts of Type III and Type II/III kerogen with good hydrocarbon potential, but is not yet mature for hydrocarbon generation. At a high degree of maturity, this potential source rock can generate moderate amounts of oil and gas.

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