Research Article

Assessment of Mineralogical and Geochemical Composition of Oligocene/Eocene Black Shale Deposits in Beni Suef Area, Egypt

Samar R. Soliman, Yasser F. Salama, Mohamed I. El-Sayed, Mohamed I. Abdel-Fattah, and Zakaria M. Abd-Allah

1Geology Department, Beni-Suef University, Beni Suef, Egypt
2Petroleum Geosciences & Remote Sensing Program, Department of Applied Physics and Astronomy, University of Sharjah, Sharjah 27272, UAE

Correspondence should be addressed to Zakaria M. Abd-Allah; zakaria.abdulah@science.bsu.edu.eg

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1. Introduction

Recently, unconventional oil and gas resources, such as oil shale and shale gas, have received more attention due to fluctuating global oil shale prices. Oil shale has good prospects for use in fields, such as chemical and building material industries, medicine, agriculture, and environmental protection [1, 2]. Oil shale is a potential source for critical energy, hydrocarbons, and other products that should be fully exploited in the future as it produces substantial gas and oil quantities upon destructive distillation [3–5]. The global interest in oil shale relates to the widespread appreciation of its value as an essential unconventional source rock or natural resource of future fuel. Although the cost is high, the energy produced through the retorting process and direct combustion of oil shale is viable [6]. The dark color is associated with the total organic carbon (TOC) content and various kerogen types and their sources [7].

In Egypt, many studies have focused on the specific stratigraphy and geology of oil shale deposits [6, 8–11]. In the depositional marine environment, biological productivity regulates the specific quality and high OM content [9]. Preserving OM depends on the sedimentation rate and oxygen level. X-ray powder diffraction (XRD) results of the black shale samples in the Maydoum quarry (west Nile Valley) revealed that montmorillonite and kaolinite are the major clay phases, whereas Ca and Qz are mostly nonclay minor phases [11]. The amorphous noise in the XRD
pattern indicated the high OM content in the black shale samples [11].

In Egypt, black shale has not been well evaluated in the study area. Therefore, this work aims to define the geochemical and mineralogical compositions of Eocene/Oligocene black shale deposits using XRD, X-ray fluorescence (XRF), TOC, and total sulfur (TS) analyses for the collected black shale samples. Moreover, seven shale samples were selected and analyzed to evaluate the significant OM content, thermal maturation, and kerogen type using the Rock-Eval pyrolysis instrument.

2. Geologic Setting and Stratigraphy

Paleogene black shale deposits were distributed along the Nile Valley in the Beni Suef area, south Cairo of Egypt. The study area is marked by excellent successions of shale deposits at two large quarries (Ghaida Al-Sharqia and Maydoum quarries). The Ghaida Al-Sharqia quarry is at latitude 28°55’N and longitude 31°2’E (east River Nile). The Maydoum quarry is at latitude 29°22’N and longitude 31°9’E (west River Nile; Figure 1). The successions were measured, sampled, and described in the field for their lithological characteristics and sedimentary structures. Macrofossils were also observed from well-defined fossiliferous beds. The shale deposits of the Ghaida Al-Sharqia quarry occurred in the El Fashn Formation (Middle Eocene) and underlies the Beni Suef Formation (Late Eocene; Saber and Salama, 2017). The presence of planktonic foraminiferal species (Truncorotaloides rohri, Morozovella spp., Truncorotaloides spp., and Acarinina spp.) supports the Late–Middle Eocene (Bartonian) age of the El Fashn Formation [10, 13, 14].

In the Maydoum quarry, shale deposits occurred in the Dabaa Formation (Oligocene). The Dabaa Formation typically comprises argillaceous and carbonaceous shales, with some glauconitic and sandy limestone interbeds with oysters and benthic foraminifera of the shallow marine environment (Figure 2). It rests conformably on the Apollonia Formation in the study area, and its age is Oligocene [15, 16].

3. Sampling and Analytical Methods

3.1. Sampling. To achieve the study’s target, many field trips have been undertaken to collect samples from the Ghaida Al-Sharqia and Maydoum quarries, where variations in the facies exist throughout (Figure 3). The samples were collected from the fresh rocks exposed inside and outside the mines. XRD and XRF analyses determined the mineralogical composition of the shale samples. Twenty-two samples were sent to the StatoChem Services Company to determine the TOC and TS contents. Moreover, seven shale samples were selected and analyzed to determine the quantity, kerogen type, and thermal maturation using Rock-Eval pyrolysis.

3.2. Analytical Methods. Some mineralogical and geochemical analyses (XRD, XRF, TOC, TS, and Rock-Eval pyrolysis) were conducted for the shale samples from

Figure 1: Satellite image of the study area (Beni Suef area), Egypt.
Maydoum and Ghaida Al-Sharqia quarries to determine the major and trace elements, OM contents, kerogen types, and thermal maturation. We can summarize the methodology of these geochemical analyses as follows.

### 3.2.1. XRD

XRD was conducted at the Faculty of Postgraduate Studies, Beni Suef University, Egypt, to identify the mineral composition of shale samples. Here, 2 g of the solid samples were crushed and placed in a 25 mm diameter sample holder and analyzed in a panalytical empyrean 202960 diffractometer using Cu–Kα (wavelength = 1.5406 Å) with electrical parameters of 40 kV and 30 mA. The scanning angles up to 80° (2-Theta) and 0.5 s scanning times.

### 3.2.2. XRF

The quantitative geochemical composition and various major and trace elements of collected shale samples...
were generated using a handheld energy-dispersive XRF. The shale samples were strongly crushed to minimize the amount of rock aggregate to <0.063 µm grain size. The crushed samples were analyzed using XRF to define the significant major element composition. Analyses were conducted on a Philips PW 1404WD-XRF using the program POWDER hosted at the National Research Center, Egypt. A mixture of 6 g of the powder sample and 1.5 g of HOECHST C-Wax were homogenized in a vibrating device and pressed into Al-cups (40 mm diameter) at 20 t-pressure.

**Figure 3:** Field photos of black shale from the Dabaa Formation in Maydoum quarry, Beni Suef area showing (a) and (b) and black shale of the El Fashn Formation in Ghaida Al-Sharqia quarry (c) and (d).

**Figure 4:** X-ray diffraction patterns for studied samples of the Dabaa Formation (a) and El Fashn Formation (b) in the study area.
| Location                        | Fm. Name         | Sample no. | SiO₂ (%) | Al₂O₃ (%) | CaO (%) | MgO (%) | Fe₂O₃ (%) | TiO₂ (%) | P₂O₅ (%) | K₂O (%) | Na₂O (%) | SO₃ (%) | Sr (%) | Ba (%) | V (%) | Ni (%) | Cr (%) | Zn (%) | Cu (%) | Zr (%) | Rb (%) |
|--------------------------------|------------------|------------|----------|-----------|---------|---------|-----------|----------|----------|---------|---------|---------|-------|-------|------|-------|-------|-------|-------|-------|
| Maydoum quarry                | Dabaa (black shale) | D1         | 45.60    | 15.97     | 4.62    | 0.85    | 0.21      | 1.20     | 2.25     | 1.02    | 250.6   | 111.6  | 93.9   | 41.3  | 85.6  | 123.1 | 10.7  | 287.7 | 55.8  |
|                               |                  | D2         | 44.25    | 15.75     | 4.05    | 0.85    | 0.22      | 1.27     | 2.51     | 1.36    | 287.4   | 127.4  | 98.0   | 36.7  | 80.6  | 112.7 | 10.8  | 249.2 | 51.8  |
|                               |                  | D2'        | 40.83    | 12.99     | 6.10    | 0.85    | 0.46      | 1.25     | 2.05     | 0.77    | 282.8   | 110.1  | 77.7   | 41.5  | 84.3  | 116.2 | 10.5  | 254.7 | 53.3  |
|                               |                  | D3         | 41.77    | 13.13     | 5.52    | 1.45    | 1.09      | 0.21     | 1.48     | 1.97    | 264.3   | 150.8  | 91.7   | 39.6  | 83.9  | 116.6 | 10.2  | 260.4 | 54.6  |
|                               |                  | D3'        | 44.19    | 14.31     | 4.81    | 1.78    | 0.93      | 0.23     | 1.30     | 2.16    | 301.6   | 239.7  | 87.2   | 43.8  | 80.3  | 118.5 | 10.5  | 260.2 | 53.7  |
|                               |                  | D4         | 43.40    | 13.94     | 4.65    | 1.59    | 1.01      | 0.20     | 1.44     | 2.23    | 280.1   | 149.6  | 91.1   | 42.8  | 89.8  | 189.7 | 9.9   | 302.5 | 50.8  |
|                               |                  | D5         | 44.64    | 16.64     | 4.32    | 1.87    | 0.61      | 0.23     | 0.94     | 2.01    | 321.6   | 129.6  | 66.8   | 28.2  | 68.2  | 74.9  | 8.6   | 321.0 | 47.4  |
|                               |                  | Average    | 50.00    | 16.66     | 5.94    | 2.02    | 11.14     | 1.00     | 0.29     | 1.58    | 323.33  | 162.77 | 98.10  | 43.23 | 93.17 | 135.06 | 11.51 | 319.60 | 60.26 |
| Ghaida Al-Sharqia quarry      | El Fashn (black shale) | E0         | 46.09    | 15.08     | 5.30    | 1.73    | 0.95      | 0.25     | 1.34     | 1.97    | 254.0   | 208.8  | 122.4  | 79.5  | 109.7 | 118.3 | 19.5  | 421.9 | 51.9  |
|                               |                  | E1         | 57.84    | 19.19     | 0.90    | 2.18    | 13.74     | 1.51     | 0.28     | 0.95    | 266.5   | 226.6  | 133.6  | 74.0  | 121.5 | 120.3 | 16.4  | 217.0 | 55.8  |
|                               |                  | E2         | 48.08    | 14.51     | 1.12    | 1.70    | 13.74     | 1.83     | 0.17     | 1.16    | 209.9   | 209.9  | 92.2   | 52.9  | 97.1  | 108.3 | 12.9  | 286.4 | 50.8  |
|                               |                  | E3         | 47.29    | 12.82     | 3.48    | 1.62    | 11.76     | 12.82    | 0.53     | 1.20    | 220.9   | 242.0  | 118.7  | 50.6  | 103.0 | 99.4  | 13.2  | 373.4 | 48.6  |
|                               |                  | E4         | 40.81    | 11.59     | 3.14    | 1.52    | 22.76     | 11.59    | 0.24     | 2.28    | 247.0   | 173.5  | 86.1   | 62.6  | 102.3 | 105.5 | 13.5  | 273.2 | 51.2  |
|                               |                  | E5         | 48.34    | 13.89     | 4.92    | 1.80    | 13.59     | 13.89    | 0.36     | 1.33    | 169.7   | 277.0  | 64.7   | 67.1  | 71.4  | 96.8  | 13.7  | 231.9 | 71.2  |
|                               |                  | Average    | 47.94    | 14.51     | 3.14    | 1.75    | 13.81     | 7.09     | 0.305    | 1.37    | 193.58  | 222.96 | 102.95 | 64.45 | 100.83 | 108.1 | 14.86 | 264.8 | 429.66 |
3.2.3. TOC and TS. The TOC for twenty-two shale samples of the Maydoum and Ghaida Al-Sharqia quarries was conducted at the StratoChem services lab (Cairo, Egypt) using the LECO C230 carbon analyzer. Before analysis, approximately 0.15 g of the bulk sample was pulverized into a fine powder and weighed in a labeled conical flask. HCL acid was added to remove the inorganic carbon, and the sample was filtered. The filtered sample was placed within a LECO crucible and dried and analyzed. Twenty-two shale samples of the Maydoum and Ghaida Al-Sharqia quarries were also analyzed using the LECO analyzer model SC632 hosted at the StratoChem Services Company, Egypt, to determine TS content. The technique involved removing any obvious contaminant material from the sample, pulverizing it, and weighed in the combustion boat. Add one scoop of the accelerator and mix thoroughly and analyze samples according to the instruction manual.

3.2.4. Rock-Eval Pyrolysis. The Rock-Eval pyrolysis analysis was conducted on shale samples of the Maydoum and Ghaida Al-Sharqia quarries using Rock-Eval 6 (RE-6). Pyrolysis is degrading OM by heating the sample where oxygen is absent. Before the analysis, obvious contaminants from the sample are removed. Approximately 0.15 g of each sample was pulverized and weighed. Pour the sample into the RE-6 crucible. Place the crucible in the RE-6 carousel and analyze samples according to the instruction manual. S1, S2, S3, and Tmax parameters were obtained.

### Table 2: TOC and TS and Rock-Eval pyrolysis of the shales from Dabaa and El Fashn formations.

| Location                  | Formation Name | Sample No. | TOC (wt %) | TS (mg/g) | S1 (mg HC/g) | S2 (mg HC/g) | S3 (mg CO2/g) | Tmax (°C) | HI (mg/g) | OI (mg/g) | PI | PY (mg/g) |
|---------------------------|----------------|------------|------------|-----------|--------------|--------------|---------------|------------|-----------|-----------|----|----------|
| Maydoum quarry            | Dabaa fm. (black shale) | D1a        | 0.31       | 0.4       | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | D1b        | 0.33       | 0.46      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | D1c        | 0.36       | 0.58      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | D2a        | 0.31       | 0.34      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | D2b        | 0.23       | 0.14      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | D3a        | 0.32       | 0.43      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | D3b        | 0.31       | 0.20      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | D3c        | 0.35       | 0.51      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | D4         | 0.13       | 0.01      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | D5         | 0.33       | 0.32      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | E0a        | 0.82       | 0.29      | 0.07         | 0.21         | 1.22          | 421        | 26        | 149       | 0.25 | 0.28     |
|                           |                | E0b        | 0.94       | 0.27      | 0.03         | 0.21         | 1.62          | 428        | 22        | 173       | 0.13 | 0.24     |
|                           |                | E0c        | 0.99       | 0.30      | 0.10         | 0.29         | 1.02          | 430        | 29        | 103       | 0.26 | 0.39     |
|                           |                | E0d        | 1.30       | 0.29      | 0.07         | 0.23         | 1.37          | 428        | 18        | 105       | 0.23 | 0.3      |
|                           |                | E1a        | 0.87       | 0.07      | 0.11         | 0.25         | 1.56          | 425        | 29        | 180       | 0.31 | 0.36     |
|                           |                | E1b        | 2.27       | 1.52      | 0.20         | 1.03         | 2.90          | 427        | 45        | 128       | 0.16 | 1.23     |
|                           |                | E1C        | 0.83       | 0.06      | 0.03         | 0.19         | 1.25          | 427        | 23        | 151       | 0.14 | 0.22     |
|                           |                | E2a        | 0.15       | 0.04      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | E2b        | 0.13       | 0.11      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | E3a        | 0.12       | 0.03      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | E3b        | 0.12       | 0.03      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | E4         | 0.18       | 0.06      | N            | N            | N             | N          | N         | N         | N | N        |
|                           |                | E5         | 0.10       | 0.05      | N            | N            | N             | N          | N         | N         | N | N        |

The TOC: total organic carbon (wt%). TS: total sulfur (wt%). S1: volatile hydrocarbons (mg HC/g rock). S2: maximum hydrocarbons yield (mg HC/g TOC). HI: hydrogen index = S2 × 100/TOC (mg HC/g TOC). OI: carbon dioxide index = S3 × 100/TOC (mg CO2/g TOC). PY: potential yield = S1 + S2 (mg/g). PI: production Index = S1/(S1 + S2). N: neglected.

4. Results

4.1. XRD and XRF Data. Across the Ghaida Al-Sharqia and Maydoum quarries, XRD was used to determine the mineralogy of shale samples. The XRD results show that montmorillonite and kaolinite are common clay phases. Quartz and calcite minerals are nonclay minerals (Figures 4(a), 4(b)). XRF determines major and trace elements of the samples (Table 1). The major and trace elements are the main results of XRF analysis of the samples (Table 1). Silica, alumina, and iron oxide were the dominant major constituents of all shale samples, where the maximum average content reached 50%, 16.66%, and 11.14%, respectively, at the Dabaa Formation in the Maydoum quarry (Table 1) and 47.94%, 14.51%, and 13.81%, respectively, at the El Fashn Formation in the Ghaida Al-Sharqia quarry (Table 1). The maximum average of trace elements recorded for Sr, Zr, Ba, Zn, V, and Cr was 323.33, 319.60, 162.77, 135.06, 98.10, and 93.17 ppm, respectively, at the Dabaa Formation and reached 193.58, 264.8, 222.96, 108.1, 102.95, and 100.83 ppm, respectively, at the El Fashn Formation.

4.2. TOC, TS, and Rock-Eval Pyrolysis Data. In this study, Table 2 summarizes the TOC, TS, and Rock-Eval pyrolysis data for the black shale of the Dabaa and El Fashn formations. The TOC shows a high OM content [17]. In the Maydoum quarry of the Dabaa Formation, the TOC values are 0.13 wt% to 0.36 wt%. The TOC for shale samples in the Dabaa Formation varied from 0.13 to 0.36 wt%.
Ghaida Al-Sharqia quarry of the El Fashn Formation varies from 0.10 wt% to 2.27 wt%. The TS content reaches 0.58 wt% in the Dabaa Formation but 1.52 wt% in the El Fashn Formation (Table 2). Furthermore, we conducted the Rock-Eval pyrolysis for shale samples of the El Fashn Formation with TOC equal to or above 0.5 wt%; therefore, the shale samples of the Dabaa Formation were neglected, as the TOC values are below 0.5 wt%. The Rock-Eval pyrolysis results indicate the OM, kerogen types, and thermal maturation quantities that will be discussed below.

5. Discussion

5.1. Mineralogical Composition. XRD results of bulk shale samples show various carbonate minerals comprising mostly calcite and noncarbonate minerals comprising quartz and variable amounts of clay minerals (Figures 4(a), 4(b)). The recognized clay mineral associations of the analyzed rock samples are identified according to Anthony et al. [18]. Smectite (montmorillonite) and kaolinite are clay minerals detected in the analyzed samples, but chlorite and illite are absent (Figures 4(a), 4(b)). These study results are similar to a historical study introduced by Zayed et al. [11]. Therefore, in both quarries, the presence of smectite and kaolinite in significant quantities indicates black shale deposition in open marine environments and the detrital origin [19, 20]. The presence of kaolinite and smectite in the marine environment was attributed to the effective chemical weathering and shale sample deposition in a

![Figure 5: Cross-plots of SiO2, CaO, TiO2, and Al2O3 and trace elements showing the correlations.](image-url)
warm humid climate [21]. The identified nonclay minerals in the shale samples using XRD are quartz and calcite minerals (Figure 4(a), 4(b)). Calcite was found in most of Nile Valley samples, indicating the marine deposition for these shales [22].

5.2. Major and Trace Elements. The high percentages of the major elements (Table 1) in the black shale deposits of the Dabaa and El Fashn Formations can be used in cement industries, ceramics, and red breaks [8, 11]. The trace elements of shale samples of Dabaa and El Fashn formations are critical sources of Sr, Zr, Ba, Zn, V, and Cr used in different chemical industries. The usage of the studied shale in drilling mud industry was supported by the high percentage of Ba in the montmorillonite clay minerals.

According to Pearson’s correlation coefficient (r) [22], the SiO2 is correlated with Al2O3 and Zr (r = 0.60 and 0.67, respectively; Figure 5). Thus, SiO2 is terrigenous in origin. Typically, CaO is of biochemical origin, whereas SiO2, Al2O3, TiO2, and K2O are of terrigenous origin [22]. However, CaO correlates with both SiO2 and Al2O3 (r = 0.78 and 0.60, respectively; Figure 5) and supports the occurrence of marine shale [23]. The low CaO values as a major oxide in this area (Table 1) reflect that the black shale samples were mostly accumulated in shallow marine environments [22].

According to the trace elements, Ni correlates well with Cr and TiO2 (r = 0.33 and 0.22, respectively; Figure 5). This correlation and the Ni content in the Dabaa Formation are lower than in the El Fashn Formation (Table 1), reflecting that the shale samples of the Dabaa Formation are mostly deposited in shallow marine environments with low TS. The high oxidation rate and/or weathering decreased the Ni content [22].

Moreover, the slightly positive correlation between Ni vs. TOC and TS reflected that the studied shale samples of Maydoum area were affected by strong weathering and oxidation more than Ghaida Al-Sharqia area. The chemical index of alteration (CIA) is an essential indicator for weathering and paleoclimatic conditions [24]. When the CIA value is 50-70, it reflects an arid and cold climate. On the other side, when it is 70-85, it indicates a humid and warm climate. Although most of CIA values in El Fashn and Dabaa formations are less than 50, the weathering line shows a semihumid climate in Ghaida area shifting to semiarid conditions in Maydoum area that indicated by cross plot of Al2O3 + Na2O + K2O vs. SiO2 [25; Figure 6]).

5.3. Organic Carbon/Sulfur Contents. TOC represents the hydrocarbon potential of formations [26–30]. The richness of OM substantially depends on parameters, such as biological productivity, sedimentation rate, clay mineralogy, oxygenation levels, and sea-level change [31]. However, preservation is a significant factor in OM richness [32]. This preservation is associated with reduction and oxidation conditions [33, 34]. Hakimi et al. [35] stated that a positive relationship between TOC and TS indicates the origin of shale samples. A similar relation was observed for TS and depositional environments. The low sulfur content reflects high accumulation of mostly black shale in the oxidizing
environment, but high sulfur refers to shale deposition in a reducing environment [35–37].

The TOC values for shale samples of the Dabaa Formation are 0.13 wt% to 0.36 wt%, reflecting a poor source of OM [38]. The organic carbon richness for the black shale of the El Fashn Formation is mostly good, as TOC values were 0.10 wt% to 2.27 wt%. However, the TS reached 0.58 wt% at the Dabaa Formation but recorded 1.52 wt% at the El Fashn Formation (Table 2). The relationship between TOC and TS (Figure 7) indicates that the Dabaa Formation was deposited in Oligocene/Miocene of very shallow marine environments (lacustrine) of warm and oxic conditions, oxidizing the OM and forming a thick amount of inert OM (black carbon) [39]. The El Fashn Formation was deposited in Middle Eocene in shallow marine environments with mostly suboxic conditions, causing slightly good preservation of OM (2.27 wt%). The presence of microfaunal, especially foraminifera, confirmed these results. All results matched well with the model (Figure 8), showing the relationship between depositional conditions, microfauna types, TOC, H/C ratio, and OM types [40].

5.4. Kerogen Type and Depositional Environments. The hydrogen index (HI) values are used to show the kerogen types [26, 35, 40–43] [44, 45]. HI below 150 mg/g refers to kerogen type III and can generate gas [38, 40, 43]. In this study, the HI values of the Dabaa Formation did not record in the Rock-Eval pyrolysis technique due to the low TOC values (Table 2), representing a residue of black carbon. However, the HI values of the black shale samples of the El Fashn Formation are largely varied, from 18 to 45 mg/g (Table 2), indicating kerogen type III that can generate natural gas (Figure 9). This kerogen type indicates that the El Fashn Formation in the Ghaida Al-Sharqia quarry was deposited in a marine environment.

5.5. Thermal Maturation and Generation Potential. Espitalié et al. [46] and Peters [38] stated that OM maturity was evaluated based on geochemical parameters, such as Tmax and the specific production index (PI) value from Rock-Eval pyrolysis results. They stated that OM is immature when Tmax values are lower than 435°C and PI values are less than 0.2. OM is mature when Tmax values are
between 435°C and 465°C and PI between 0.2 and 0.4. In our study, the Tmax values of the El Fashn Formation shales were between 421°C and 430°C and PI between 0.13 and 0.31 (Table 2), indicating immature source rocks. To evaluate the maturity and kerogen type, shale data were plotted on an HI versus Tmax diagram [46]; Figure 10). The results indicated that the shales contained immature kerogen type III that, by surface retorting, can generate natural gas.

Finally, the shale deposits in the study area are none laminated with benthic foraminifera and oysters that confirmed the deposition in oxic to suboxic shallow marine environments. The Lagenids and Buliminids foraminifera in the shale deposits of the studied area suggest low oxygen level. However, the presence of these genera such as Lenticulina and Cibicidoides indicates oxic environments [47]. All results matched well with the model in Figure 8, showing a relationship between depositional conditions, microfauna types, TOC, H/C ratio, and OM types [40].

6. Conclusions

By the end, the main results of this work can be summarized in the following points [49, 50]:

(i) The higher smectite and kaolinite clay phase contents indicate detrital origin and deposition in shallow marine environments.

(ii) The high percentage of SiO2, Fe2O3, and Al2O3 of the Dabaa and El Fashn formations supported the usage of the studied shale in cement industries and red breaks. Moreover, the high percentage of Ba in montmorillonite of the studied shale will be more applicable in the drilling mud producing.

(iii) The TOC results reflected that the Dabaa Formation (Oligocene) at the Maydoum quarry has poor OM content related to low preservation efficiency and oxic environments that oxidized some OM, forming black carbon. However, the El Fashn Formation (Middle Eocene) at Ghaida Al-Sharqia has good OM content due to deposition in shallow marine environments with suboxic conditions that lead to good OM preservation.

(iv) Rock-Eval pyrolysis results of the black shale indicated kerogen type III of terrestrial origin of the El Fashn Formation due to the good preservation of the high OM content in suboxic shallow marine environments.
(v) Thermal maturation from the geochemical parameters of Tmax and PI from Rock-Eval pyrolysis reflected that the collected shale deposits in the El Fashn Formation are highly immature, as observed in the outcrop or near the surface; however, during surface retorting, it can generate natural gas.

Data Availability

The geochemical data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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