Mineralogy, Geochemistry and Hydrocarbon Potentiality of Eocene-Oligocene Black Shale Deposits of Beni Suef Area, Egypt

Introduction

Black shale deposits are widespread in the Eocene-Miocene successions at Beni Suef area in the stable shelf of Egypt. The studied sections are located on both sides of the Nile Valley at Beni Suef City (Figure 1) including Maydoum, Qarara, Heiba, Abiayd, Ghaida Al-Sharqia and Homret Shaibun sections. The observed rock units are from older to younger as follow: Qarara, El Fashn, El Qurn, Tarbul and Maadi formations of Eocene age, Dabaa Formation of Oligocene age and Moghra Formation of Miocene age (Saber and Salama 2017) (Figure 2). The foraminferal contents of these rock units allowed us to detect the depositional environments as well as to assign the age. In Maydoum section at the Western bank of the Nile Valley, the recorded foraminferal species from the shale deposits are mainly 194 benthic species belonging to 92 genera and 58 planktonic species belongs to 18 genera such as Orbulina, Praeorbulina, Trilobatus, Globigerinoides, Turbo, Dentoglobigerina, Globoturbototalita, Globorotaloides, Tenuitella, Paragloborotalia, Subbotina, Globigerina, Globigerinella, Ciperoella and Catapsydrax. Based on these foraminifer's species, the age of shale deposits at Maydoum section is of Oligocene – Middle Miocene. However, in the studied sections at the Eastern bank of the Nile Valley, the shale deposits are of Middle – Late Eocene age based on their foraminferal contents. Moreover, the lithology, facies and the recorded foraminifer's species of the studied shale deposits suggest an open marine, inner to outer shelf depositional environments of water depth not exceed 200 meters and low to moderate oxygenated condition.

Black shale is one of Egypt’s resources that are left abandoned and not used well. Therefore, this work concentrates on evaluation the black shale deposits of the studied locations to determine the mineralogy, geochemistry, organic carbon richness and the generation potentials of hydrocarbons, and detect the best economic aspects of these widespread black shale deposits in Beni Suef area, Egypt.

Method and/or Theory

The shale samples were collected from the Maydoum quarry (Figure 3) and Ghaida Al-Sharqia quarry. Moreover, four field trips have been done to collect rock samples from the outcrop of Gabal Homret Shaibun, Gabal Abiayd, Gabal Qarara and Gabal El Heiba at the eastern side of Nile Valley in Beni Suef area. The mineralogical composition of shale samples can be easily approached through X-ray Diffraction (XRD) and X-ray Fluorescence Spectroscopy (XRF). Analyzed major elements were SiO2, TiO2, Al2O3, Fe2O3, MgO, CaO, Na2O, K2O, SO3 and P2O5. Trace elements analysed were F, Ag, As, Ba, Bi, Br, Cd, Cl, Co, Cu, Cr, Cs, Ga, Hg, Mn, Mo, Ni, Pb, Rb, Sb, Se, Sn, Sr, Th, U, V, W, Zn and Zr. Thirty five shale samples of the Maydoum and Ghaida Al-Sharqia quarries were carried using the LECO C230 carbon analyzer to determine the TOC, TC and TS content. Moreover, twenty shale samples were analyzed for Rock-Eval pyrolysis to determine the quantity, kerogen types and thermal maturity of organic matter, and to detect the expected hydrocarbons that yield from the shale deposits.

Results and Discussion

In the present work, smectite (montmorilonite) and kaolinite are the most abundant clay minerals encountered in the analysed samples using XRD analysis, but chlorite and illite are absent (Figure 4). The same conclusion was introduced by Zayed et al., (2018). The recognized clay mineral associations of the analysed rock samples were identified according to Anthony et al., (1990). Therefore, the abundance of smectite and kaolinite in the studied shale deposits indicated the detrital origin and deposition in open marine environments. However, the smectite dominance in clay minerals suggested a terrestrial provenance that has a warm and semi-arid climate conditions (Temraz 2005). Quartz was found as an important non-clay mineral in all samples. Also, carbonate minerals detected by XRD are calcite. Generally, calcite was found in most Nile Valley samples, in addition to the presence of foraminifers’ fossils may indicate the deposition of these formations in a marine environment.
Figure 1 Satellite image of the study area (Beni Suef area with red square), Egypt.

Figure 2 Stratigraphy of Beni Suef area (one exposed section) (after Saber and Salama 2017)

Figure 3 Field photos of mining activities of the black shale deposits in the studied locations.

Figure 4 XRD analysis shows the clay and non-clay minerals of the shale samples.
The results of XRF analysis revealed that the silica is the dominant constituent of all studied shale samples (Figure 5). The average content of silica is 41.24%, while Alumina reached 17.43%. The SiO$_2$ is positively correlated with Al$_2$O$_3$ and Zr that can be explained by a terrigenous origin as a part of the clay minerals and detrital silicates. But SiO$_2$ is negatively correlated with TiO$_2$ and K$_2$O which reflected biochemical origin.

The hydrocarbon potentiality of the source rocks can be evaluated by determining the amount of TOC in the analysed samples (Jarvie, 1991, Abd-Allah et al., 2019 and 2020). The organic geochemistry of the studied shale samples reflected that the TOC content reached 2.27 wt.%, TC reached 8.02 wt.% and TS was 1.52 wt.% at El Fashn Formation at Ghaida Al-Sharqia Quarry, but thus percentages reached 0.41, 1.59 and 0.82 wt.% for TOC, TC and TS respectively for Oligocene Dabaa Formation at Maydoum Quarry. This difference in the results related to the deposition of Dabaa Formation was deposited in warm and oxic environments that lead to oxidize the organic matter. On the other hand El Fashn Formation deposited in Middle Eocene age in open marine with suboxic environments resulted in a good preservation of the organic matter that has the ability to yield biogenic gas of terrestrial origin (Type III kerogen) as resulted from the Rock-Eval pyrolysis (Figure 6). The generation potential of the El Fashn Formation is poorly due to the low level of thermal maturation as these shale deposits existed at the outcrop of the studied locations. Therefore, these shale samples should be retorted at the surface or in-situ to extract the biogenic gas. The low values of the sulphur content reflected oxic and suboxic environments whereas the organic matter decayed and lost large amount of hydrogen in the form of H$_2$S gas, and this process led to decrease the TOC in the study area specially for Dabaa Formation (Oligocene age) at Maydoum quarry. Therefore, these shales are suitable for cement industry and building bricks, and the possibility to extract biogenic gas at Beni Suef area.

![Graph 1](image1.png)

**Figure 5** XRF analysis shows the relationships between SiO$_2$, Al$_2$O$_3$ and K$_2$O (after Temraz 2005) for the shale samples.

![Graph 2](image2.png)

**Figure 6** Hydrocarbon generation potential (A) (after Peters and Casa 1994) and types of organic matter (B) (after Hunt 1996 and Abdel-Fattah et al., 2017) of El Fashn Formation, Beni Suef area.
Conclusions

The lithology, facies and the recorded foraminifer's species of the studied shale deposits suggested an open marine, inner to outer shelf depositional environments. Abundance of smectite and kaolinite in the studied locations indicates the detrital origin and deposition in open marine environments. Also, the smectite dominance in clay minerals suggested a terrestrial provenance that had not attained intensive weathering; with a warm and semi-arid climate and the resulted materials were carried by fluvial action conditions. The SiO$_2$ is considered to be dominantly terrigenous in origin and may be based on a biogenic origin. The results of TOC and Rock-Eval pyrolysis reflected that the Dabaa Formation is poorly organic matter content due to low preservation efficiency in warm and oxic environments led to oxidize the organic matter forming black carbon, but El Fashn Formation deposited in Middle Eocene age in open marine with suboxic environments that led to good preservation the organic matter that has the ability to yield biogenic gas of terrestrial origin after retorted it.

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References


