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Characterization and beneficiation of the Egyptian black shale for possible extraction of organic matter

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ABSTRACT

The present paper focuses on obtaining concentrate enriched with organic matter that could be suitable for a retorting process from black shale; this is black shale from the Safaga area on the Red Sea Coast. X-ray diffraction and optical polarising microscope are used in evaluating black shale minerals. Attrition scrubbing and flotation were conducted for enrichment of organic matter in the black shale sample. Mineralogical studies revealed that black shale samples contain bituminous calcareous clay stone, quartz, apatite and pyrite. Rabah mine black shale contains 28% organic matter. The results of the different separation techniques indicate that attrition and flotation techniques successively enriched the organic matter in the black shale. The organic matter could be enriched in the black shale and obtained a concentrate with 59% assaying and 85% recovery.

1. Introduction

Black shale is a term used in industry for sedimentary formations comprising clay deposits with layers containing a black organic matter, that may be a polymer called kerogen or carbonaceous matter (coal). Sedimentary formations containing kerogen are called "oil shale", while the formations containing coal are called "carbonaceous shale". Both of them are common and well distributed in Egypt.

The energy situation is one of the most difficult problems facing our world today. The growing shortage of crude petroleum and its increasing cost has resulted in renewed worldwide interest in black shale. Black shale represents a potential source of energy and hydrocarbons, which should be fully utilized in the near future [1]. In addition, black shale is used in the cement industry as a source for energy and luminous silicate components. Other potential byproducts include carbon fibers, absorbent carbon, carbon black, bricks, construction and decorative building blocks, soil additives and rock wool. Recently, it was proved that black shale can be used for the production of filled grease such as lithium lubricating grease [2].

The beneficiation of oil shale to recover kerogen enriched products was proposed as early as 1920 by Dolbear [3]. Later, the US Bureau of Mines and others reported work on beneficiation of western oil shale [4,5]. Meanwhile, Reisberg and Fahlstrom published the results on flotation and oil agglomeration of finely ground oil shale particles in the range of 15–150 mm [6,7].

They reported that the separation of kerogen rich particles with an efficiency of 70% was obtained. Heavy liquid separation was reported to upgrade oil shale, but the kerogen recovery in the enriched products in most cases ranged from 14% to 50% of the feed [8].

Conventional processing of oil shale is a three step operation, which includes mining, crushing, and retorting. Oil shale may contain 10–35% (by weight) kerogen which decomposes and yields crude oil when heated to 400–500 °C. The beneficiation step offers the potential of improving the economy of retorting while achieving other benefits such as reducing energy [9,10]. The extremely fine size of the enriched flotation concentrates should favor improved kinetics and chemical reactivity of the shale during conventional retorting, hydroretorting or other novel conversion processing. They showed that flotation can reject 50–70% (by weight) non-fuel minerals before processing, and improve the productivity of the reactor.

The present paper focuses on the enrichment of organic matter of black shale from Rabah mine, Safaga area on the Red Sea coast to obtain concentrates rich in organic matter, which can be used in a retorting process as an energy source.

1.1. Occurrence of black shale in Egypt

Black shales in Egypt are widely distributed in the Western Desert, Eastern Desert and Sinai. They cover a wide age spectrum from

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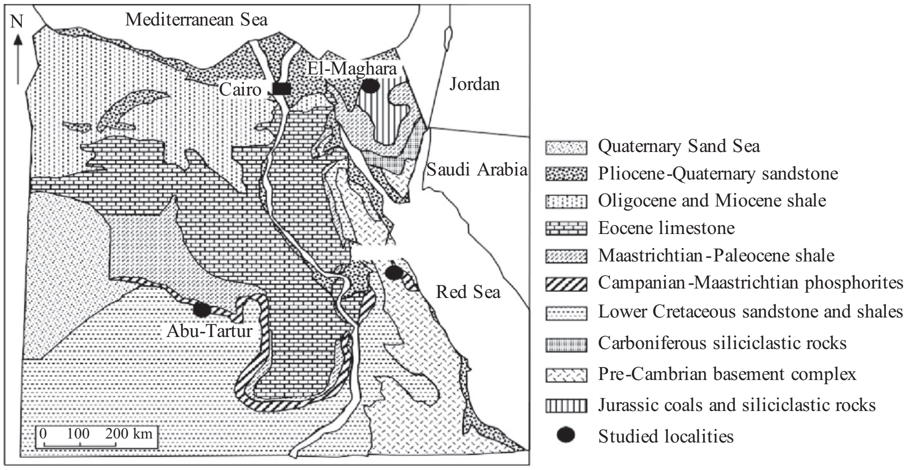

Fig. 1. Locations of main black shale occurrence in Egypt.

middle Jurassic to upper Cretaceous (Campanian–Maastrichtian black shale of Duwi Formation). They also deposited in different depositional environments including non marine (Jurassic black shale) and marine (black shale of Duwi Formation). They are also associated with other ores such as coal in the Maghara area, Sinai or phosphorite deposits in the Red Sea and Abu Tartur areas (Fig. 1).

1.2. Location and geologic setting

The Maghara area is located approximately 200 km to the northeast of Cairo about 50 km south of the Sinai Mediterranean Coast. It is a rectangular massive about 45 km long and 30 km wide and covers approximately 1300 km^2 situated between longitude 33°10′ and 33°35′E and latitude 30°35′ and 30°50′N [11]. It is the only major Jurassic outcrop in North Sinai and hosts the economic coal beds. Coal-bearing formation consists of 215 m thick carbonaceous, banded, silty sandstone with a few earthy grey limestone and contains Bathonian fossils. The thickness of the main coal seam in the Maghara area ranges from 130 to 190 cm and underlain and overlain and by thin black shale beds ranging in thickness from 10 to 50 cm (Figs. 2 and 3).

Late Cretaceous sedimentary sequence of the Duwi Formation is well exposed in Quseir–Safaga coastal plain along the Red Sea coast. The Duwi Formation is exposed along approximately 40 km long scarp on the western side of Duwi Range situated between longitude 34°10′ and 37°35′E and latitude 26°35′ and 28°50′N.

Glenn and Arthur and Darwishe considered the Duwi Formation in the Red Sea area as late Campanian to early Masstrichtian in age [11–12]. Darwishe subdivided the Duwi Formation in the in Red Sea area into four lithological members (Fig. 2) [12]. The lower member is dominated by yellowish-gray, laminated, silty claystone, grayish-yellow, laminated, siliciclastic sandstone, gray, laminated shale, and yellowish-gray, finely laminated to thinly bedded porcelanite that are intercalated with thin beds of phosphorites, marl, oyster fragment-rich calcarenite, and yellowish gray, hard, weakly laminated chert. The middle member ranges in thickness from 5 to 7.5 m and is characterized by soft, yellowish-gray laminated shale that are intercalated with 2–25 cm thick, yellowish-gray, massive, hard, coarse-grained, siliceous, phosphorites. The upper member ranges in thickness from 3 to 13 m, and is composed of yellowish-gray, parallel to cross-laminated, oyster-fragments-rich calcarenite with thin intercalations of siltstone, shale, chert, and phosphorites. The uppermost member is

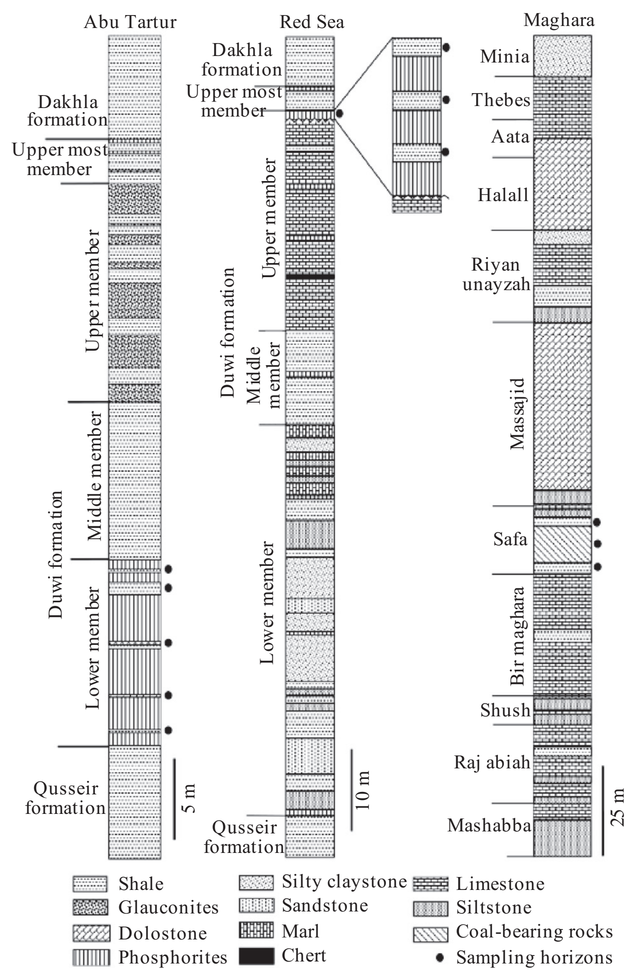

Fig. 2. Stratigraphy of black shale in Egypt.

1.2–5 m thick and is composed of gray, massive, coarse-grained phosphorites intercalated with thin laminated black shales and overlain by grayish-brown shale that contains marly concretions in its middle part.

The Abu-Tartur plateau lies 600 km southwest of Cairo in the Western Desert between Dakhla Oasis to the west and Kharga Oa-