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Mineralogy and source rock evaluation of the marine Oligo-Miocene sediments in some wells in the Nile Delta and North Sinai, Egypt

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ABSTRACT

This paper aims to study the mineralogical composition and determine the petroleum potential of source rocks of the Oligocene-Miocene sequence in the Nile Delta and North Sinai districts. The studied interval in the five wells can be divided into five rock units arranged from the top to base; Qawasim, Sidi Salem, Kareem, Rudeis, and Qantara formations.

The bulk rock mineralogy of the samples was investigated using X-Ray Diffraction technique (XRD). The results showed that the sediments of the Nile Delta area are characterized by the abundance of quartz and kaolinite with subordinate amounts of feldspars, calcite, gypsum, dolomite, and muscovite. On the other hand, the data of the bulk rock analysis at the North Sinai wells showed that kaolinite, quartz, feldspar and calcite are the main constituents associated with minor amounts of dolomite, gypsum, mica, zeolite, and ankerite.

Based on the organic geochemical investigations (TOC and Rock-Eval pyrolysis analyses), all studied formations in both areas are thermally immature but in the Nile delta area, Qawasim, Sidi Salem and Qantara formations (El-Temsah-2 Well) are organically-rich and have a good petroleum potential (kerogen Type II–oil-prone), while Rudeis Formation is a poor petroleum potential source rock (kerogen Type III–gas-prone). In the North Sinai area, Qantara Formation has a poor petroleum potential (kerogen Type III–gas-prone) and Sidi Salem Formation (Bardawil-1 Well) is a good petroleum potential source rock (kerogen Type II–oil-prone).

1. Introduction

The Miocene succession in Egypt represents about 12% of the total land surface (Ball, 1952). Lying unconformably on the older rocks, they extend from near Cairo westwards across the northern part of the Western Desert into Libya. They are forming a plateau rising gradually to south and reaching height over 200 m. Also, they occur in hills to the east of Cairo, as well as, along both sides of the Gulf of Suez and near the Red Sea coast in both Egypt and Sudan (El-Heiny, 1979).

Numerous studies have investigated the petroleum potential and hydrocarbon characteristics of many localities in Egypt (Rohrback, 1983; Mostafa, 1993; Mostafa et al., 1993, 1998; Bakr and Wilkes, 2002; El-Gayar et al., 2002; Hegazi et al., 2004; Barakat et al., 2005; El-Shahat et al., 2009; El Diasty and Peters, 2014; and El Diasty et al., 2015). Both Miocene and pre-Miocene sediments are sufficiently mature to generate oil; Eocene and Lower Miocene source rocks correlate closely with produced crude oils which appear to be related to a single, widespread source rock (Rohrback, 1983).

This work studies five wells, three of them are located at the northeastern of the Nile Delta: the Boughaz-1 Well was drilled to a total depth of about 3540.9 m by Continental Delta Oil Company (lat. 31° 09′ 24.6″ N, long. 32° 40′ 47.55″ E), the San El-Hagar-1 Well was drilled to a total depth of about 3772 m by Continental Delta Oil Company (lat. 30° 29′ 13″ N, long. 31° 50′ 53″ E), and the El-Temsah-2 Well was drilled to a total depth of about 4689 m by Mobil exploration Egypt Inc. Company (lat. 31° 47′ 7.38″ N, long. 32° 10′ 26.68″ E). While the last two wells are located at the northwest Sinai region, the Malha-1 Well was drilled to a total depth of about

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2198 m by Egyptian Petroleum Company (E.G.P.C) (lat. 30° 59′ 12″ N, long. 33° 20′ 32″ E) and the Bardawil-1 Well was drilled to a total depth of about 4490 m by (E.G.P.C) (lat. 31° 08′ 14″ N, long. 33° 07′ 35″ E). All of these are onshore wells except the El-Temsah-2 Well (offshore) (Fig. 1).

This study aims to determine the bulk mineralogical composition for the subsurface Oligo-Miocene sequence in two localities (Nile Delta and North Sinai), and the source rocks evaluation in terms of petroleum potential and thermal maturity.

2. Lithostratigraphy

The Oligo-Miocene sequence in this study was represented by five rock units arranged for the top to base as follows: Qawasim, Sidi Salem, Kareem, Rudeis and Qantara formations. The litho- and biostratigraphy of these rock units in the five wells are previously discussed by Faris et al., (in press), and their lithostratigraphy are shown in Fig. 2.

3. Materials and methods

Twenty eight cutting samples were selected from the five studied wells in the Nile Delta and North Sinai areas. These samples were analyzed by using a BRUKER D8 Advance model X-ray diffractometer (XRD) in Geochemistry Research Laboratories of Istanbul Technical University (ITU/JAL), Istanbul, Turkey. Using a Rigaku Rad-1 X-ray powdered diffractometer with energy ranging from 30 kV to 10 m A. Small pieces of sample were dried and finally powdered with agate mortar and pestle. The mineralogical investigation was carried out on the bulk rock, and then slides are scanned at a scan speed of 1° 2θ"/minute at a range from 2° 2θ to 72° 2θ. Minerals were identified by their characteristic reflections (Moore and Reynolds, 1989). It was operated with scanning rate 0.1° 2θ/sec., 1 × 104 CPS, time constant 1, slit 0.3 using Ni filtered Cu K-∝ radiation. Samples were interpreted using X,Pert HighScore Plus program, version: 2.2b (2.2.2), licensed to: I.T.U. Istanbul Technical University, Faculty of Chemistry and Metallurgy, Maslak (License No. 92000060).

The organic geochemical analyses of Total Organic Carbon (TOC) and Rock-Eval pyrolysis were performed in 19 samples (13) from the Nile Delta area (Boughaz-1, San El-Hagar-1 and El-Temsah-2 wells) and (6) samples from the North Sinai area (Malha-1 and Bardawil-1 wells). These analyses were conducted at TPAO (Turkish Petroleum Corporation) Research Center's Organic Geochemistry Laboratories (Ankara, Turkey) using a RockEval-6 device (including TOC determinations), IFP 160000 (French Institute of Petroleum) standard on 100 mg pulverized rock samples which were heated to 600 °C in the helium atmosphere, in order to determine the amount of organic matter, the petroleum generation potential as well as the thermal maturity.

4. Results and discussion

4.1. Mineralogical composition

All samples were analyzed by XRD and a semi-quantitative determination of the minerals was conducted based on measuring peak height ratio (Carver, 1971). The mineral identification was carried out based on the discussion of Moore and Reynolds (1989). The (001) and (002) reflections of kaolinite are 7.16 Å and 3.58 Å, respectively. Non-clay minerals were identified by their maximum reflections as follows: quartz (3.34 Å), calcite (3.04 Å), halite (2.82 Å), feldspar (3.26 Å) and dolomite (2.89 Å). In addition, barite was identified using 3.44 Å and 3.1 Å peaks, but it was disregarded from semiquantitative calculations as it is a contamination from drilling mud. The results of mineralogical analysis are given in Table 1.

In this study, the sediments of the Nile Delta area are mostly

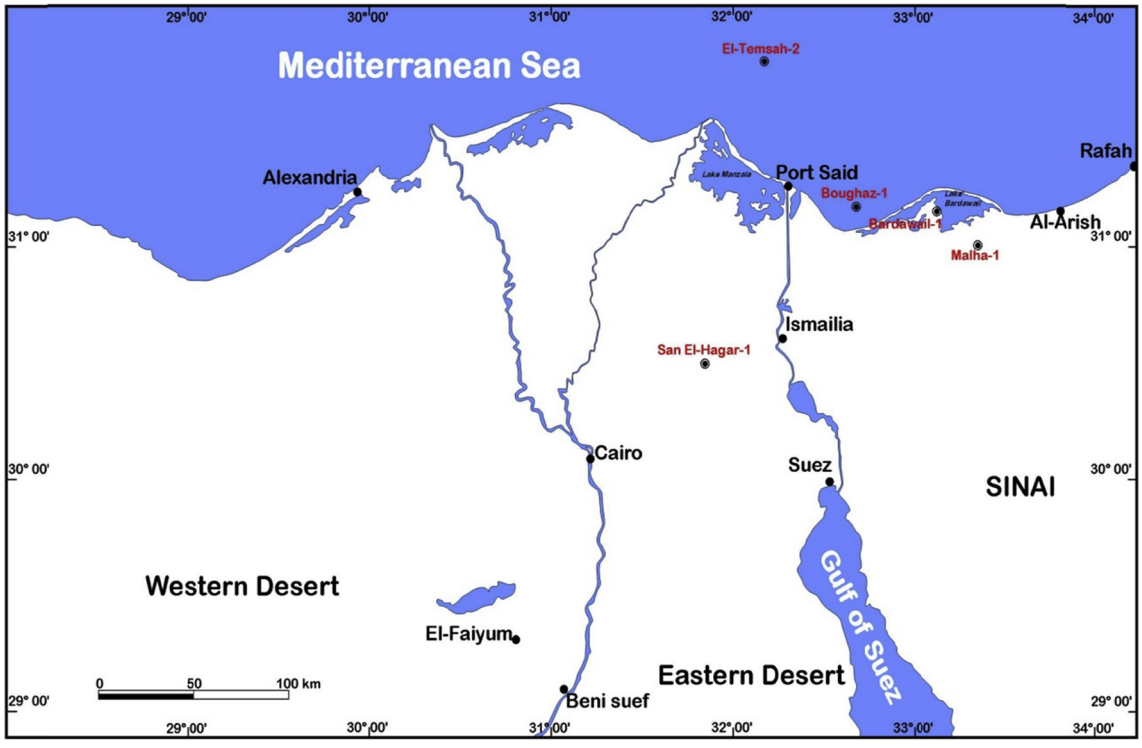

Fig. 1. Location map of the studied wells.