International Journal of Coal Geology 131 (2014) 326–343

Contents lists available at ScienceDirect

International Journal of Coal Geology

journal homepage: www.elsevier.com/locate/ijcoalgeo

Source rock potential and paleoenvironment of the Miocene Rudeis and Kareem formations, Gulf of Suez, Egypt: An integrated palynofacies and organic geochemical approach

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ARTICLE INFO

Article history:
Received 5 May 2014
Received in revised form 25 June 2014
Accepted 26 June 2014
Available online 12 July 2014

Keywords:
Palynofacies
Vitrinite reflectance
TOC
Rock-Eval pyrolysis
Gulf of Suez
Egypt

ABSTRACT

A study on source rock characterization and paleoenvironmental interpretation has been carried out on a relatively thick Miocene sedimentary succession from three wells (GH 404-2A, GH 420-1, SA-E6A) in the southern Gulf of Suez, Egypt. The compilation of detailed optical investigations, including palynofacies analysis, spore coloration index (SCI), vitrinite reflectance (VR_r) and source rock geochemical data enables a detailed evaluation of organic matter (OM) richness, kerogen type, and thermal maturation level. Despite their high content of calcium carbonate (up to 52%), the studied sediments yielded sufficient palynologic residue for a detailed palynofacies and organic petrographic study. The palynomorph content comprises mainly marine components, essentially dinoflagellate cysts and accessorily microforaminiferal linings, while terrestrial-derived material is relatively rare. Persistent occurrence of amorphous organic matter (AOM) indicates that dysoxic to anoxic conditions prevailed throughout the deposition of the investigated sediments.

The main objective of this study is to combine organic geochemical and palynological data in an attempt to assess the source rock potential of the Rudeis and Kareem formations in the Gulf of Suez. These data, in addition, also allow for the reconstruction of the depositional environment.

The present investigation employs multimode microscopic methods using transmitted white light along with incident light fluorescence microscopy. For the first time, geochemical and petrographic analyses performed on bulk rock samples and palynological residues demonstrate that both the Rudeis Formation and the Kareem Formation are mainly of kerogen type III or mixed type II/III. Independent thermal maturation specific parameters such as Rock-Eval T_{max}, VR_r and SCI indicate an immature to early mature stage. Palynofacies analyses, combined with organic geochemical data indicate that the Rudeis Formation was deposited under shallow to open marine conditions, whereas the overlying Kareem Formation was formed mainly in an open marine setting.

1. Introduction

The Gulf of Suez is a location of extensive hydrocarbon plays and has excellent hydrocarbon potential. As an oil province, it is ranked seventh in terms of production among the major graben systems or rift basins in the world (Clifford, 1986; Schlumberger, 1995), with a prospective sedimentary basin area of approximately 19,000 km^2. This province has more than 1000 exploration wells, with 240 oil discoveries in more than 80 oil fields and is also considered as being the most prolific oil province rift basin in Africa and the Middle East (Schlumberger, 1984; Alsharhan, 2003).

The Miocene sedimentary successions in the Gulf of Suez of Egypt are a prime target in the search for new petroleum discoveries. Several studies on organic geochemistry and petrography have been frequently carried out on these successions by oil companies (mostly unpublished reports). To the authors' knowledge, very few have so far been published in the scientific literature, in particular studies combining organic geochemistry, palynofacies and applied spore coloration index (SCI) analyses.

The source rock potential of the Miocene successions within the Gulf of Suez was geochemically studied by several authors, e.g. Rohrback (1982), Barakat (1982), Shahin and Shehab (1984), Mostafa and Ganz (1990), Mostafa (1993), Mostafa et al. (1993), Alsharhan and Salah (1994), Alsharhan (2003), Younes and Philp (2005), and El Diasty and

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http://dx.doi.org/10.1016/j.coal.2014.06.022
0166-5162/

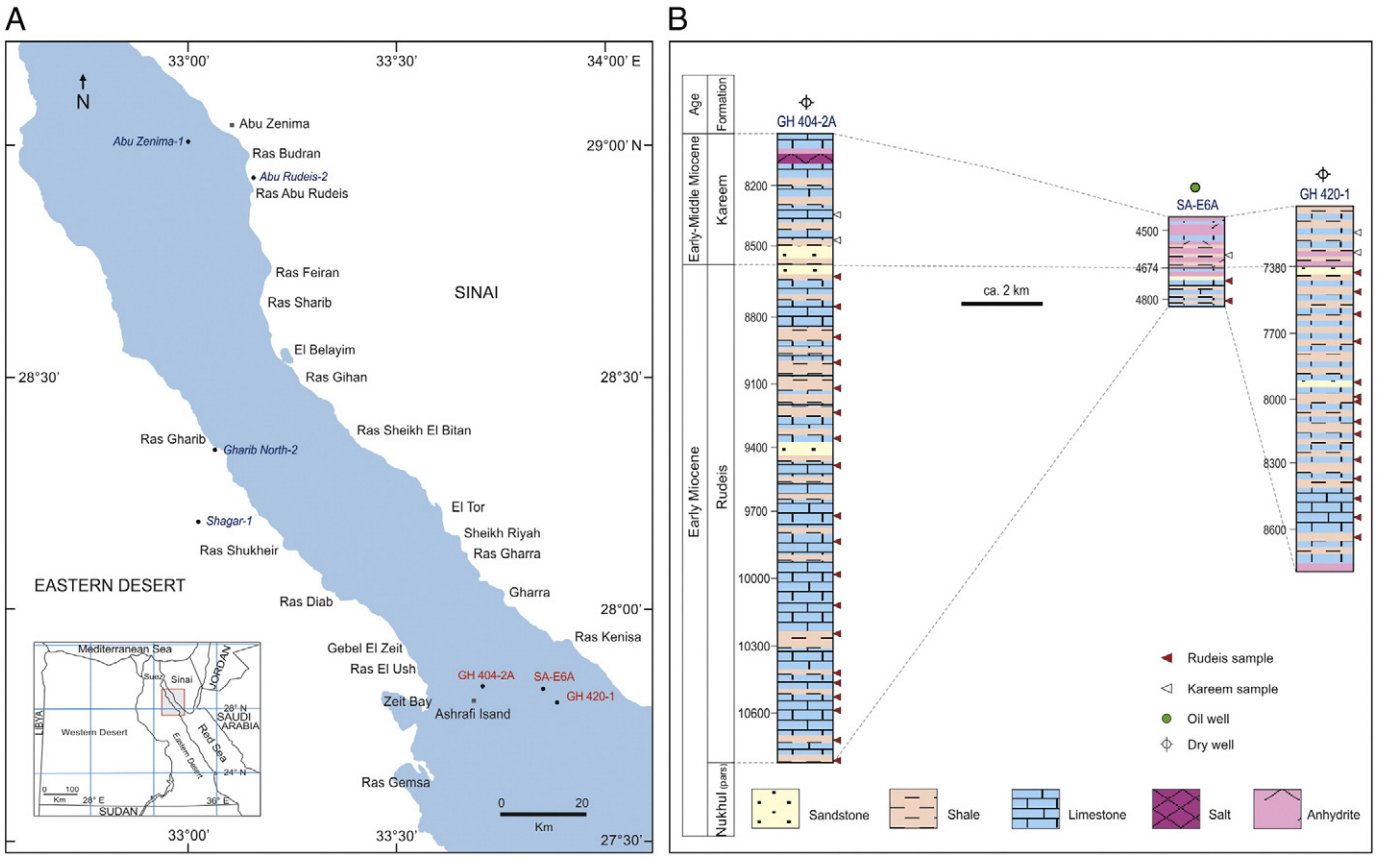

Fig. 1. A) Location map showing the studied wells. B) Lithostratigraphic correlation of the Rudeis and Kareem formations in the studied wells, Gulf of Suez, Egypt (modified after GUPCO, 1983, 1986, 1988), the distances between wells are shown in relation to their geographic positions.

Peters (2014). They suggest five potential source rock intervals within the Late Cretaceous and Miocene successions based on total organic carbon (TOC) and Rock-Eval data.

The present attempt focuses on two of these source rocks which are within the Rudeis and Kareem formations. Within the study, we provide the first comprehensive palynofacies and basic organic geochemical and petrographic evaluation of samples from the Miocene Rudeis and Kareem formations, which were penetrated by the wells GH 404-2A, GH 420-1, and SA-E6A in the southern part of the Gulf of Suez, Egypt (Fig. 1A). Although mainly aimed at determining source rock potential for hydrocarbons in the two studied formations, palynofacies data also offer a good possibility to develop a more complete, holistic assessment of the prevailing paleoenvironmental and depositional conditions, mainly in terms of oxygenation levels (e.g. anoxic versus oxic), source of kerogen (e.g. marine, lacustrine, terrestrial), paleoenvironmental preferences reflected by specific palynomorph groups (e.g. colonial algae, such as *Botryococcus* and *Pediastrum*) and depositional setting (e.g. shallow marine). All of these parameters are considered in a detailed way and hence increase the current knowledge about the paleoenvironment of the Rudeis and Kareem formations within the examined area.

2. Geologic setting

The Gulf of Suez is a shallow and narrow body of water, which was formed as a failed intracontinental Cenozoic rift system. It is approximately 300 km long, forming the northern extension of the Red Sea, and covers an area of about 25,000 km^2 at average water depth ranging from 55 to 100 m (Schlumberger, 1984; Young et al., 2000). Rifting occurred during the separation of the African Plate and Sinai sub-Plate in the latest Oligocene–Early Miocene (Boukhary et al., 2012). The Gulf of Suez is tectonically subdivided into three provinces (Bosworth and McClay, 2001 and citations therein). These are the northern Darag, central Belayim and southern Amal–Zeit provinces that are respectively separated by Galala–Abu Zenima and Morgan accommodation zones. In addition, Bosworth and McClay (2001) assumed that the onset of rifting is no younger than 25–27 Ma for the southern part of the Gulf, 25–23 Ma for the central Gulf and ~23.5 Ma for the northern Gulf and the Cairo–Suez relay zone.

Sedimentation rate and tectonic subsidence during the initial phase of rifting were slow and the corresponding stratigraphic sequences show an upward transition from continental red beds and volcanics of the Abu Zenima Formation to marginal marine mixed siliciclastic-carbonate lithology of the Nukhul Formation (e.g. Patton et al., 1994).

Geomorphologically, the Gulf of Suez represents a rejuvenated, slightly arcuate NW–SE topographic depression, previously known as the Clysmic rift or Clysmic gulf, named after the ancient Roman settlement of Clysma that occupied the present site of the city of Suez (Robson, 1971). It extends northwestward from 27° 30′ N to 30° 00′ N, and its width varies from about 50 km at its northern rim to about 90 km at its southern end where it merges with the Red Sea (Bosworth and McClay, 2001).

3. Lithostratigraphic framework

The stratigraphic column in the Gulf of Suez can be subdivided into three megasequences: a pre-rift succession (pre-Miocene or Paleozoic–Eocene), a syn-rift succession (Oligocene–Miocene), and a post-rift succession (post-Miocene) or Pliocene–Holocene (Fig. 2). These units exhibit clear variations in their lithology, thickness, areal distribution, depositional environment and also hydrocarbon potential (e.g. Alsharhan, 2003).