ORIGINAL ARTICLES

Special Effects of Diagenesis on Storage Capacity of Thebes Formation at Gebel Rewagon Area, Eastern Desert, Egypt.

Tarek Y. M. A. El-hariri, Essam M.A. Abu Assy and Gamal El-Dein A. Ibrahim

Egyptian petroleum research institute

ABSTRACT

The aim of this study is to concentrate on the lithostratigraphy, microfacies associations, depositional environments, diagenetic processes petrophysical parameters of the Thebes formation (Early to Middle Eocene) exposed at Gebel Rewagen area, Eastern Desert, Egypt. The study revealed the presence of seven microfacies types: bioclastic wackstone, foraminiferal wackstone, wackstone, nemolitic wackstone, forameniferal wackstone, forameniferal packstone and fossiliferous wackstone. The diagenetic processes which affected the rocks in Thebes Formation are compaction, neomorphism, micritization, cementation, dolomitization and dissolution. The Thebes Formation sediments were deposited in restricted, shelf lagoon and open circulation environments. The petrophysical characteristics of the studied rocks show that the forameniferal wackstone microfacies in the Thebes Formation have a high porosity and permeability; thus, this microfacies is considered as best place as good storage capacity.

Key words: Microfacies association, depositional environments, diagenetic processes, petrophysical parameters, Thebes Formation.

Introduction

A striking feature of the early to middle Eocene series present on the stable shelf of Egypt is the occurrence of limestones with alternating flint facies. Together with the underlying Cretaceous and Paleocene deposits, these rocks form tectonically related topographic features along the Red Sea coastal strip near the Duwi Range (Fig. 1). They occupy the troughs of synclinal-like structures encircled by the Red Sea crystalline hill range (Said, 1990).

During the last four decades there has been an upsurge of interest in the sedimentation and stratigraphic framework of the lower Eocene Thebes Formation in the Eastern Desert of Egypt (e.g. El-Tarabili, 1966; Snively et al., 1979; Said, 1990; Abdel Maguid, 1992; Aref, 1995; Speijer et al., 1996). However, few comprehensive studies have been carried out on the diagenetic history of this formation (e.g. Snively, 1984; El Sheshtawy, 1990; Keheila and El-Ayyat, 1990; Abu Shama, 1996). The present work provides an evaluation for the diagenetic continua of the early to middle Eocene rocks in the Gebel Rewagen area, south Duwi Range (Fig. 1) based on integrated petrographic and isotopic studies. The various diagenetic products, their sequence of occurrence and their spatial distribution are described. Their respective diagenetic environments and the factors responsible for their replacement are evaluated.

Geological Setting:

The Red Sea mountain range is terminated eastwards by a narrow discontinuous strip made up of upper Cretaceous / lower Eocene sedimentary strata. Rocks comprising the Thebes Formation constitute bold white cliffs, which run sharply towards the north with a dip slope of 15–20°. In the Eastern Desert, the Thebes Formation conformably overlies the late Paleocene to early Eocene Esna Formation (Said, 1990). The early Eocene age for this formation is based on its microfaunal content (e.g. Said, 1960, 1990; Aref, 1995). This formation is located within the Morozovella formosa and M. arganensis zones (Said, 1990). The Thebes Formation in the Eastern Desert consists of thinly bedded limestones and chalky limestones (with Operculina libyca and Nummulites spp.) with apparent interbedding of flint bands and nodules. Snively et al. (1979) mentioned that the lower Eocene rocks in the Eastern Desert of Egypt represent a shallowing-upward succession that indicates a period of local uplift coupled with a period of rapid sea-level fall. They divided the Thebes Formation in the Eastern Desert into three informal members: a lower member made up of 40 – 60 m pelagic carbonates with chert followed by a middle member composed of around 100 m thinly bedded limestone with cherts and nodular carbonates and a thin (0 – 25 m) upper member made up of fine-grained...
limestone. However, Speijer et al. (1996) proposed that the Paleocene/lower Eocene succession in southern Eastern Desert was deposited during a period of more or less stable sea-level within a middle neritic zone at paleodepth range from 75 to 100 m.

**Fig. 1:** Location and geological map of the studies area at Gebel Rewagen, Eastern Desert, Egypt, after, E.G. S. & M. A.; 1994).

**Lithostratigraphy:**

The Thebes Formation was named by Said (1960) for the limestone exposures a Gebel Gurnah, west of Luxor and near the site of the ancient Egyptian capital of Thebes.

The Thebes Formation crops out on the cliff faces of many tilted fault blocks such as, Gebel Duwi, Um Hammad, Wasief, Rewagen act……).

It conformably overlies the Esna Formation and unconformably underlies the Nakheil Formation in the Un Hammad fault – block.

It is built up mainly of thick succession of white fossiliferous limestone with extensive chert lenses. It reaches about 111.5 m. in thickness. Many sections are extremely thinner as a result of extensive erosion of the upper portion, see Figs. 2&3).

**Fig. 2:** Photograph showing the studied Thebes Formation (Early to middle Eocene) succession in Gebel Rewagen area, Eastern Desert Egypt.
Fig. 3: Lithostratigraphic column of Thebes Formation (Early to Middle Eocene) at Gebel Rewagon, Eastern Desert, Egypt.

The lower part of the Thebes Formation consists of laminated and thinly bedded limestone with massive chalk inter-beds. Thin skeletal limestone bands with scoured base are not uncommon. Chert is abundant on the upper portion of the lower part, occurring as scattered concretions and lenses.

The predominantly pelagic deposition of the lower part is changed upward into heterogeneous succession of nodular limestone, intra-formational conglomerate and foraminiferal lime sand with extensive hard ground. The chert nodules and chalk are rare in the upper part.

The intra-formational conglomerates are composed mainly of abraded limestone grains embedded in a poorly sorted matrix of sand sized limestone. Fossiliferous and skeletal limestone horizons are common. Trace fossils are common, especially *Thalassinoides* and *Chondrites*. The facies association, fossil content and primary structures assume deposition on a shallow marine carbonate platform.

The upper most part of Thebes Formation is made up of fine grained limestone with oyster limestone inter beds.
Methodology:

The present work aims to flash up at the lithostratigraphical, microfacies association, Diageness and petrophysical properties of the Thebes Formation at Gabel Rewagon. The derived samples were studied in the Egyptian Petroleum Research Institute, as follows:

1- Microscopic Investigation:

Twenty eight thin sections were prepared for the petrographic study and lithostratigraphic of the rocks of Thebes Formation, to determine the microfacies association, and diagenetic processes of the studied rocks. The carbonate microfacies were described, discussed, interpreted and photographed.

2- The petrophysical properties:

Bulk and grain density, porosity and permeability were measured for twenty eight two samples at the core lab. of the Egyptian Petroleum Research Institute.

Microfacies Association:

The study of the microfacies association was carried out to interpret and delineated the environmental conditions during deposition and to understand the diagenetic processes affecting the consolidation rocks. For this purpose, thin-sectioned were performed examined petrographically. In the present study the standard microfacies types of Wilson (1975) based on Dunham, (1962) and Emby, A.F. & Klovan, J.E. (1972) classification of carbonate were used in description and identified microfacies associations of the studied rock succession. The study revealed the presence of seven types of microfacies, which are as follows:

1- Bioclastic wackstone:

This type of microfacies is very common in limestone beds of the Thebes Formation at Gebel Rewange area. The limestone is pale white, moderately hard, bedded to banded, contain thin shale interbeds. The microfacies are mainly composed of micrite with fossils content. The fossils are mainly benthonic foraminifera and different type of shell fragments which consists about 15 to 20% from the rocks. Most shells are composed of micro and drusy spar crystals as represented in samples No. 1 – 5 (Pl. 1, A). The matrix was also affected by aggrading neomorphism and compaction processes, low porosity and restricted depositional environments.

2- Foraminiferal wackstone:

This facies is composed of abundant faunal content cemented with sparite and micrite. The limestone is grey, pale grey, hard, thickly bedded, fossiliferous. The microfacies is mainly composed of benthonic foraminiferal consisting from 25 to 30% of the rock. The allochemical components are densely packed in micrit and orthosprite which are representing in samples No. 6 – 8 shown in (Pl. 1, B). This facies is affected by micritization, neomorphism and cementation, medium porosity and shelf lagoon depositional environments.

3- Wackstone:

This facies is represented by, highly bioturbate limestone which is recorded in most of the studied outcrops. The microfacies is white massive thickly bedded mainly micrite as representing in samples No. 9 – 12 and showing in (Pl. 1, C). This facies is affected by micritization, medium porosity and restricted depositional environments.

4- Nemolitic wackstone:

This facies is represented by snow white, moderately hard, with silty shale intercalations, cherty nodules beds with high fossil content. Microscopically, the microfacies is mainly composed of niomolite and algae cemented by sparry calcite as represented in samples No. 13 - 17 and showing in (Pl. 1, D). This facies was deposited in shelf lagoon environment and medium porosity.
5- Foraminiferal wackstone:

This facies is represented by white to grey, fissile, with cherty bands and nodules fossiliferous. The microfacies is mainly composed of planktonic forminiferal consisting from 20 to 30% of the rock cemented by sparite and calcite. This facies is represented by samples No. 18 - 20 shown in (Pl. 1, E & F). This facies is affected by cementation and dissolution, high porosity and open circulation depositional environments.

6- Foraminiferal packstone:

This facies is represented by grey, dolomitic hard, chert nodules and bands, highly fossiliferous, with coquina beds. The microfacies is mainly composed of planktonic forminiferal consisting from 30 to 40% of the rock cemented by microsparite. This facies is represented by samples No. 21 - 24 shown in (Pl. 1, G & H). This facies is affected by compaction, dolomitization and cementation, low to medium porosity and open circulation depositional environments.
7- Fossiliferous wackstone:

This facies is represented by grey, banded, moderately hard, siliceous nodules and thin bands, fossiliferous. The microfacies is mainly composed of benthonic foraminiferal and shell fragments consisting from 10 to 20% of the rock cemented by calcite. This facies is represented by samples No. 25 - 28 shown in (Pl. 1, I). This facies is affected by compaction, and cementation, low to medium porosity and restricted depositional environments.

Petrophysical Properties:

Petrophysical properties (grain density, bulk density, packing index, porosity, permeability, porosity ratio and reservoir quality index) have a great role in defining the best location with the higher storage capacity.

All of these parameters were determined in the laboratories of the Egyptian Petroleum Research Institute (EPRI), (Table 1). The porosity is determined according to the methods of Preabrojenky (Kobranova, 1962; Dakhanova, 1977 and Ragab et al. 1985), the permeability according to (Leverson , 1967). The packing index (PI ) is defined by El Sayed (1993), porosity ratio defined by Amfule et al. (1993) and reservoir quality index defined by Diebber Tiab & Donadson (1996).

Table 1: The petrophysical parameters of Thebes Formation at Gebel Rewagen, Eastern Desert, Egypt.

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<th>Bulk density (g/cm³)</th>
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<th>Perm. (mD)</th>
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In the present study twenty eight rock samples have been collected from the (Early to Middle Eocene) Thebes Formation at the Gebel Rewagen area, Eastern Desert, Egypt. The bulk density is ranging from 1.83 to 2.57 gm/cm, the lowest value is represented by sample No. 16 which is a nemolitic wackstone microfacies, while the highest value is represented by sample No. 28 which is a fossiliferous wackstonemicrofacies. The grain density ranging from 2.41 to 2.69 gm/cm3, the lowest values is represented by sample No. 23 which is a forameniferal packstonemicrofacies, while the highest values is represented by sample No. 16 which belong to the nemolitic wackstone microfacies.

The porosity ranging from 4.3 to 32.1%, the lowest values represent the samples No. 3. This sample is characterized by bioclastic wackstone microfacies, while the highest values is represented by sample No. 16 which belong to the nemolitic wackstone microfacies.

The permeability of the studied samples is ranging from 0.10 to 0.940 mD, all samples give low values except samples No. 18, 19 and 20, these samples represented by forameniferal wackstone microfacies.
The packing index is ranging between 1 and 1.4494, the lowest values represent the samples No. 18. This sample is characterized by forameniferal wackstone microfacies, while the highest values is represented by sample No. 16 which belong to the nemolitic wackstone microfacies.

The porosity ratio is ranging between 0.0417 and 0.4728; the lowest values represent the samples No. 2. This sample is characterized by bioclastic wackstone microfacies, while the highest values is represented by sample No. 16 which belong to the nemolitic wackstone microfacies.

The quality reservoir index is ranging between 0.0679 and 0.5879; the lowest values represent the samples No. 14. This sample is characterized by nemolitic wackstone microfacies, while the highest values is represented by sample No. 19 which belong to the forameniferal wackstone microfacies.

Statistical analysis of the petrophysical data show clearly that, the highest porosity and permeability values are recorded in forameniferal wackstone. The porosity increases with the decrease in the bulk density, the permeability of the studied samples, similar to porosity increase when the bulk density is deceasing. Also, the quality reservoir index and porosity ratio increase when the porosity and permeability increase, (Fig. 4).

**Depositional Environment:**

However, modern depositional environments can only be fully understood when the appropriate physical and microfacies association are known. Weber & Van Geuns, 1990 and Snedden & Nummedal, 1991, dealing with the depositional environments and facies, as well as lithostratigraphic and economic stratigraphic aspects of certain sedimentary rock types. The concept of sedimentary models is important for environmental analysis. The model of concept of (Wilson, 1975) is applied in this study. Thebes Formation consists mainly of chalky limestone and limestone intercalation with bands and nodules chert. It is distinguished by the following microfacies associations, (Fig. 5).
Summary and Conclusions:

The study of diagenetic processes, microfacies associations and petrophysical parameters of the rock units of the Thebes Formation at Gebel Rewagon, Eastern Desert, Egypt reveal that the carbonate microfacies are characterized by the following:

- **Bioclastic wackstone** microfacies characterizes by restricted environments which are affected by neomorphism and compaction processes that resulted low porosity and permeability, also has a poor storage capacity.
- **Foraminiferal wackstone** characterizes by open circulation environments which are affected by micritization, neomorphism and cementation processes, medium porosity and low permeability, also has a poor storage capacity.
- **Wackstone** microfacies characterizes by restricted environments which are affected by micritization processes, medium porosity and low permeability, also has a poor storage capacity.
- **Nemolitic wackstone** characterizes by shelf lagoon environment, which are affected by compaction and cementation processes, medium porosity and low permeability, also has a poor storage capacity.
- **Foraminiferal packstone** characterizes by open circulation environments which are affected by compaction, dolomitization and cementation processes, low to medium porosity and low permeability, also has a poor storage capacity.
- **Fossiliferous wackstone** characterizes by restricted environments which are affected by compaction and cementation processes, low to medium porosity and low permeability, also has a poor storage capacity.

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