



Sequence stratigraphic analysis and depositional evolution of the Upper Cretaceous deposits in Ras Budran oil field, Gulf of Suez, Egypt

Mohamed M. Elhossainy¹ · Abdelhamid M. Salman² · Mohammad A. Sarhan³  · Nabil M. Al-Areeq⁴ · Hamed A. Alrefae¹

Received: 3 February 2021 / Accepted: 25 May 2021 / Published online: 5 June 2021
© Saudi Society for Geosciences 2021

Abstract

The Upper Cretaceous deposits represent significant oil reservoirs in several fields of the Gulf of Suez province, Egypt. The present work aims to study these sediments in Ras Budran oil field in view of sequence stratigraphic analysis. Five third-order depositional sequences were determined for the Upper Cretaceous section in Ras Budran field depending on the analysis and interpretation of the integrated well logging and biostratigraphic datasets. The five sequences are separated by six sequence boundaries and were classified into their systems tracts signifying several sedimentation patterns of progradation and retrogradation. The first depositional sequence corresponds to the Cenomanian-early Turonian Raha and Abu Qada formations classifying into transgressive and highstand systems tracts. The second sequence comprises the Late Turonian Wata Formation subdividing into transgressive and highstand systems tracts. The third sequence embraces the Coniacian–Santonian Matulla Formation subdividing into lowstand, transgressive, and highstand systems tracts. The fourth and fifth depositional sequences coincide with the Campanian-Maastrichtian Brown limestone and Sudr Chalk marking transgressive and highstand systems tracts. The well-documented Maastrichtian-Paleocene boundary marks the last sequence boundary at the top of the studied succession and is strongly controlled by synsedimentary tectonics associated with the Syrian Arc tectonism. The Late Cretaceous depositional history at Ras Budran field was dominated by relative sea level fluctuations. The rising in relative sea level was controlled by the global sea level rise together with basin subsidence, whereas the drop in relative sea level was controlled by the basin filling.

Keywords Sequence stratigraphy · Upper Cretaceous · Well logs · Depositional evolution · Gulf of Suez Basin

This article is part of the Topical Collection on *Current Advances in Geological Research of Egypt*

Responsible Editor: Zakaria Hamimi

✉ Mohammad A. Sarhan
msarhan@du.edu.eg

¹ Department of Geology, Faculty of Science, Kafrelsheikh University, Kafrelsheikh 33516, Egypt

² Department of Geology, Faculty of Science, Assiut University, Assiut 71516, Egypt

³ Geology Department, Faculty of Science, Damietta University, New Damietta 34517, Egypt

⁴ Department of Geology and Environment, Faculty of Applied Sciences, Thamar University, Dhamar, Yemen

Introduction

The Gulf of Suez represents a main petroleum province in the Egyptian territory. It is produced from various types of rocks belonging to basements, Paleozoic, Mesozoic, and Cenozoic (Said 1990). In addition, the area of the sedimentary basins within the Gulf of Suez is approximately estimated to be 19,000 km² and is characterized by outstanding hydrocarbon potential (Alsharhan 2003). The Gulf of Suez district includes many oil fields that have been found in onshore and offshore areas.

Ras Budran oil field (the present study) is a main field within the Gulf of Suez area (IHS E 2006). It is located in the central portion of the gulf (offshore concession in Belayim), ~ 4 km west of the Sinai coast as shown in Fig. 1. Discovery history within this field began in 1987 by drilling of the “exploration well” EE 85-1. The well reached a total depth of 1264 ft and cumulatively produced about 12,000 barrel oil

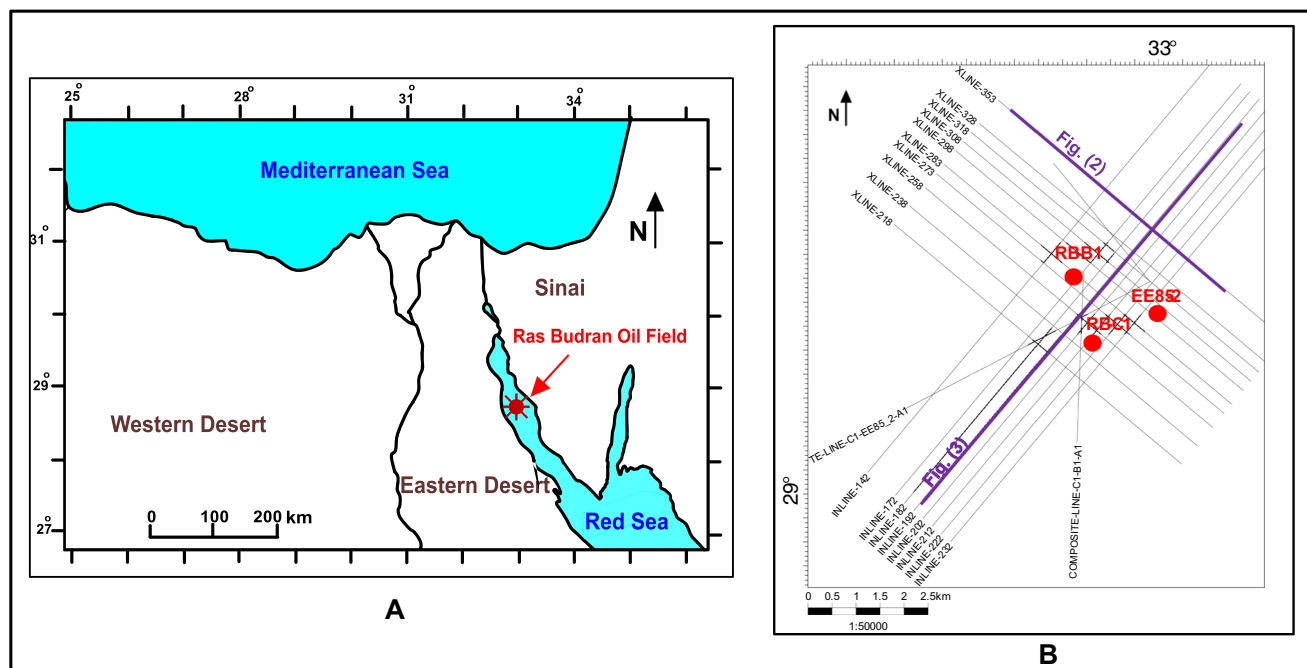


Fig. 1 **A** General map shows the location of Ras Budran oil field in the Gulf of Suez area. **B** Study area with seismic lines and well locations

per day) from five Cretaceous and Paleozoic Nubian sandstone reservoir (IHS E 2006).

Several studies have been conducted on the current study area that began with Moon and Sadek (1923); Said (1962, 1990); Zein El-Din and Taher (1973); Mohsen et al. (1975); Koldewijn (1984); Al Naggar and Helaly (1985); Rose et al. (1985); Chowdhary et al. (1986); Chowdhary and Taha (1987); Moller (2001); Alsharhan (2003); Awad and Serag El Din (2009); Mandur and Baioumi (2009); Atia (2014); Atia et al. (2015); El-Gendy et al. (2017); and Nabawy and Barakat (2017). These previous literatures were concerned with sedimentological investigations, structural evolution, and petrophysical studies on Ras Budran, Gulf of Suez, Egypt. Few studies about the sequence stratigraphy and depositional evolution of the area were published (e.g., Alsharhan 2003; Bauer et al. 2003).

The importance of sequence stratigraphic concepts arises from understanding the changes in spatial and temporal sedimentation and their accumulation patterns in relationships of sea level fluctuation (Emery and Myers 1996; Posamentier and Allen 1999; Catuneanu et al. 2009; Al-Areeq et al. 2020).

Generally, the geological history in the Gulf of Suez region ranges from Paleozoic age to Recent, which is characterized by three stages of deposition in relation to the events of the rift (Early Paleozoic-Eocene Pre-rift, Early-Middle Miocene Syn-rift, and Late Miocene-Pliocene Post-rift stages) (Said 1990) as shown in Figs. 2 and 3. The Gulf of Suez rift lies within the Arabian-Nubian shield and is considered as a part of the first continental crust from the Proterozoic to the Lower Paleozoic

that formed during the extensive Precambrian Pan African tectonic events (Said 1990).

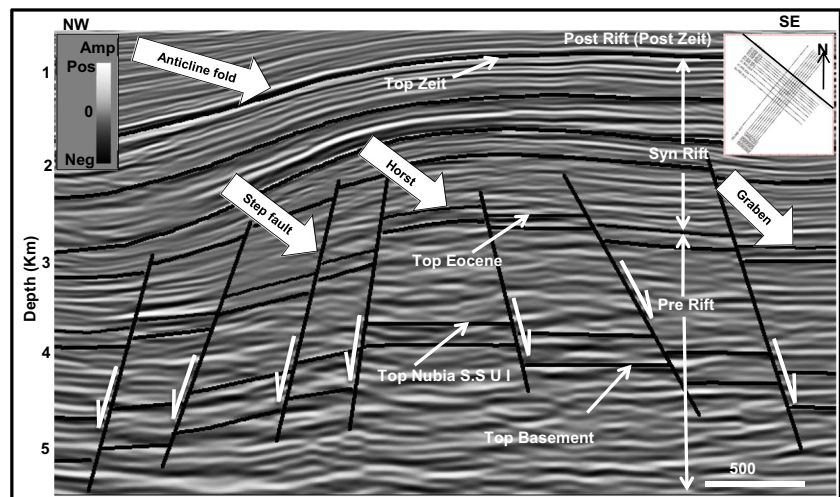
The main aim of the current work is to determine the sequence stratigraphic framework of the subsurface deposits of the Upper Cretaceous within Ras Budran oil field, Gulf of Suez, Egypt. The evolution of depositional process of the Upper Cretaceous sediments in the studied field through the previous sequence stratigraphic analysis will be inferred.

Materials and methods

The accessible data in the current study encompasses twenty-one 2D seismic sections covering the study area (Fig. 1B). The seismic data has been tied to three wells (RB-B1, RB-C1, and EE85-2). The available wireline logs data for these wells are gamma ray, resistivity, sonic, density, and neutron. Moreover, an unpublished biostratigraphic report has been used to delimit the sequence boundaries in the area of study.

The seismic interpretation step in the present study started with picking the clearest seismic reflectors along the area of study as well as the related faults over the grid of seismic lines. This step has revealed the abundance of step normal faults associated with several horsts and grabens in addition to the presence of anticlinal fold structure affected Ras Budran oil field (Figs. 2 and 3). The redundancy of these structural elements in addition to the highly deformed and discontinuous seismic reflectors prevented the accurate picking for the key surfaces used in seismic sequence stratigraphic analysis (e.g.,

Fig. 2 Interpreted NW-SE seismic section shows the main structural features of Ras Budran oil field. Note the presence of anticlinal fold structure and the abundance of step normal faults and the associated horsts and grabens



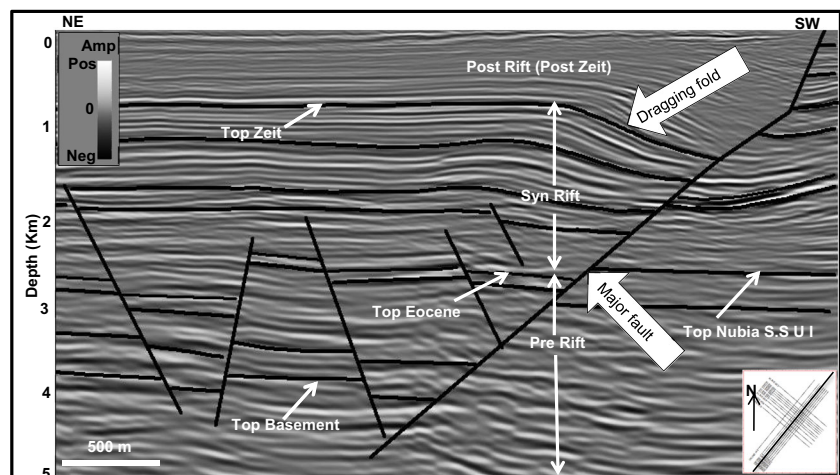
sequence boundaries, transgressive surfaces, maximum flooding surfaces) for the Upper Cretaceous succession in the study area. Accordingly, the sequence stratigraphic analysis step for the Late Cretaceous section in Ras Budran oil field has been conducted depending on the available wireline logs for the three examined boreholes (RB-B1, RB-C1, and EE85-2) in addition to the obtainable biostratigraphic report.

The accessible well logging data, particularly gamma ray log and occasionally neutron-density log (marked by facies changes), helped to detect the positions of the clearest sequence boundaries within the log interval according to Van Wagoner et al. (1990), Emery and Myers (1996), and Catuneanu (2006). Also, the duration of the depositional sequences in the present study as third order is built based on the terminology given by Goldhammer et al. (1990).

Stratigraphic framework

The stratigraphic framework in the present study is classified in six rock units and is shown in detail below (Fig. 4).

Fig. 3 Interpreted NE-SW seismic profile displays the redundancy of structural elements (faults and fold) controlling the Ras Budran oil field in the Gulf of Suez Basin



Raha Formation (Cenomanian)

The name Raha Formation was given by Ghorab (1961). It represents the beginning of the Cenomanian age that marked the onset of marine transgression within the Gulf of Suez area. It unconformably overlies the Nubia Sandstone, whereas it conformably underlies the Abu Qada Formation (Alsharhan 2003).

Generally, the Raha Formation is subdivided into three parts: lower, middle, and upper parts (IHS E 2006). The lower part consists mostly of sandstone intercalated with minor shale beds. The middle part is made predominantly of limestone interbedded with shale beds, whereas the upper section consists of intercalations of sandstones and minor shales. In the current work, the Raha Formation is penetrated at all the studied boreholes, and it is represented by a quite variable thickness of about 160 m, 130 m, and 123 m in RB-B1, RB-C1, and EE85-2 wells, respectively (Figs. 5, 6, 7). Concerning the matter that the upper part of this formation is missed in EE85-2 well, it may be due to the uplift.

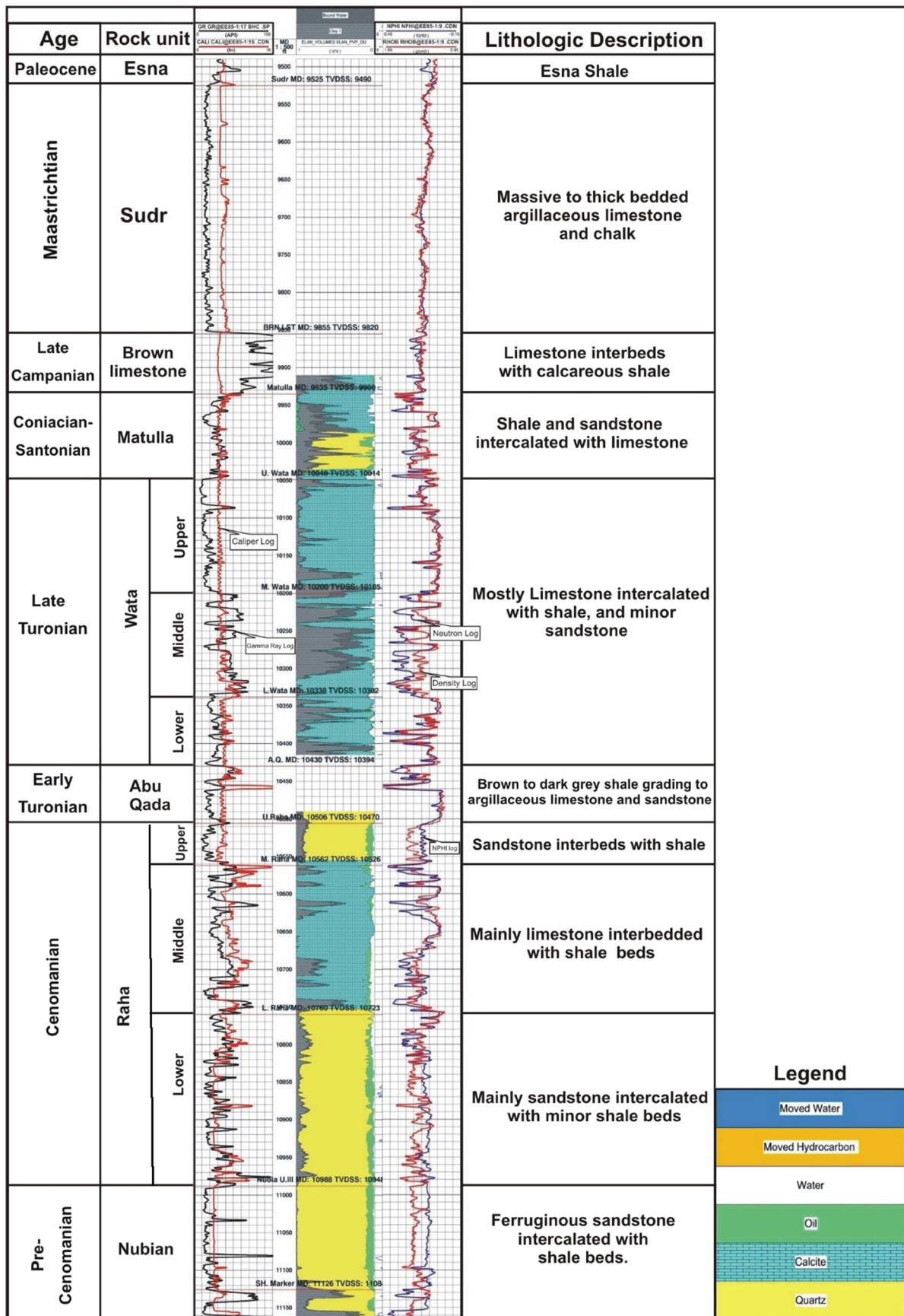


Fig. 4 Compiled lithostratigraphic division and description of the Upper Cretaceous succession, Ras Budran field, Gulf of Suez, Egypt

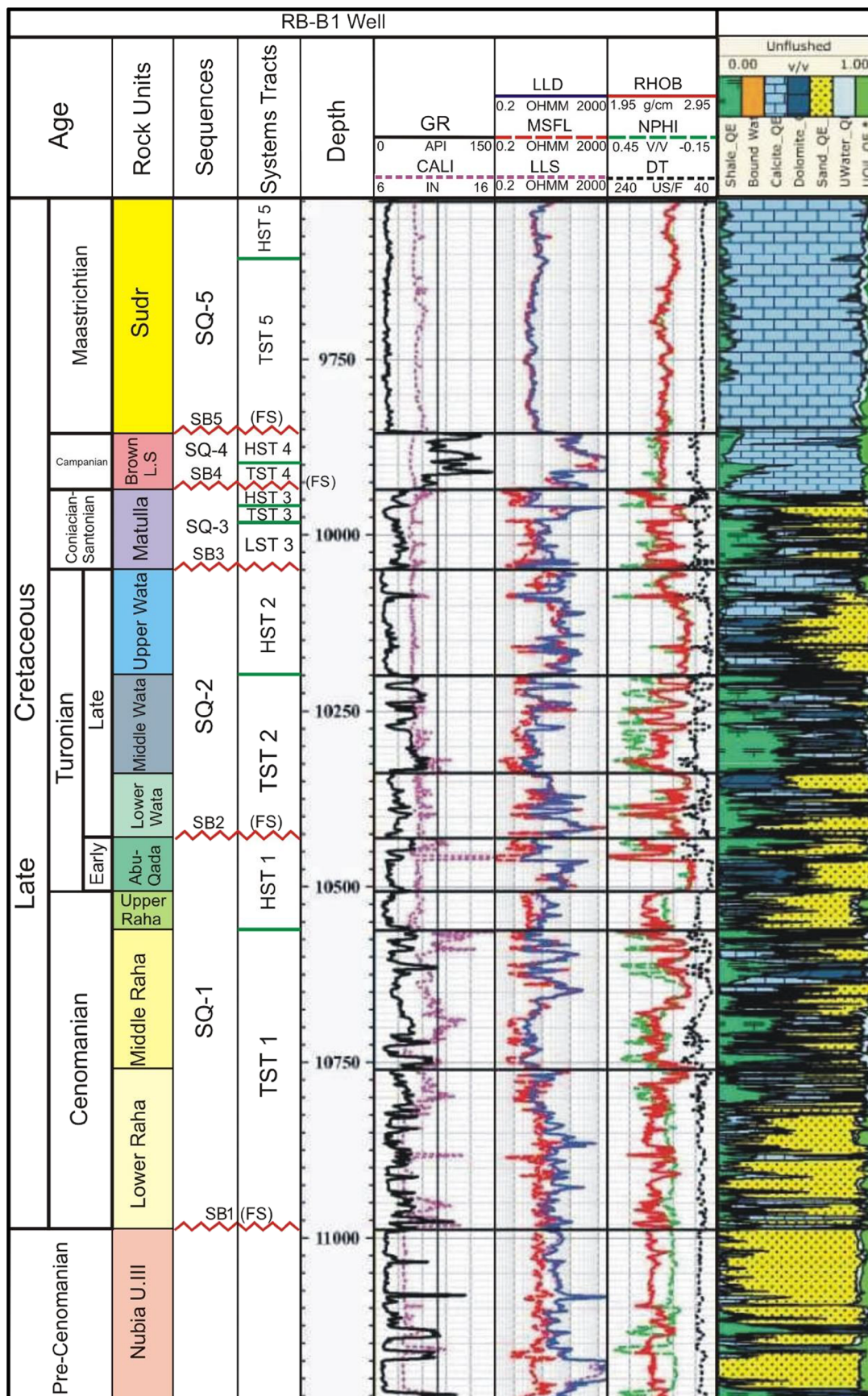


Fig. 5 Sequence stratigraphic classifications of the Upper Cretaceous section at RB-B1 borehole

Abu Qada Formation (early Turonian)

Ghorab (1961) named the Abu Qada Formation. Alsharhan (2003) stated that this formation unconformably underlies the Wata Formation. It consists mainly of brown to dark grey shale grading to argillaceous limestone and sandstone (IHS E 2006).

In the current study, this formation is penetrated at the studied boreholes except EE85-2 well, which may be due to the uplift. It reaches about 25 m and 15 m in RB-B1 and RB-C1 wells (Figs. 5 and 6). It encloses the *Whiteinella archeocretacea* zone with the early Turonian age (Shahin and Kora 1991).

Wata Formation (late Turonian)

This unit marks the progressive marine transgression that continued during the late Turonian time across the Gulf of Suez district (Ghorab 1961). Alsharhan (2003) stated that this formation is unconformably overlain by the Matulla Formation. Generally, the Wata Formation is subdivided into three parts, lower, middle, and upper, that mainly consist of limestone and intercalations of shale and slight sandstone (IHS E 2006). Additionally, it comprises plenty of ammonite, molluscan, and foraminiferal fossils (Bauer et al. 2001, 2003; Mandur and Baioumi 2009).

In the current work, the Wata Formation exists in all the studied boreholes with variable thickness due to the missing of many of its parts. Hence, the Turonian Wata Formation was deposited on different settings of the structural highs and lows in the study area, which may have been due to the echo of the Syrian Arc System (Kuss et al. 2000). The total thicknesses of this unit range about 127 m, 27 m, and 51 m in RB-B1, RB-C1, and EE85-2 wells, respectively (Figs. 5–7).

Matulla Formation (Coniacian–Santonian)

It was introduced by Ghorab (1961). The Matulla Formation consists of intercalated grey shale, sandstone, and argillaceous limestone. It is characterized by its planktonic foraminiferal content, which includes *Dicarinella concavata* and *D. asymetrica* zones revealing Coniacian–Santonian age (Fig. 8). It is unconformably overlain by the Brown limestone (Alsharhan 2003).

The Matulla Formation is recorded in all studied wells except RB-C1 well; this may be due to continuous uplift process. It reaches about 38 m and 92 m in RB-B1 and EE85-2 wells (Figs. 5 and 7).

Brown limestone (late Campanian)

It consists mainly of limestone interbedded with rich calcareous shale. The lower section of the sequence contains chert,

whereas the upper section contains more argillaceous components (IHS E 2006). It is assigned to the Campanian age, depending on the occurrence of foraminiferal fauna: *Globotruncanita elevata* and *Globotruncana ventricosa*. Brown limestone is unconformably overlain by the Sudr Chalk (Alsharhan 2003). Also, it is represented by a stratigraphic discontinuity due to the lack or non-deposition of the latest Campanian *Globotruncanita calcarata* zone (Fig. 8).

In the current work, Brown limestone is documented in all the studied wells except for the RB-C1 well. This may be due to the continued uplift. It reaches about 26 m and 73 m in RB-B1 and EE85-2 wells (Figs. 5 and 7).

Sudr Chalk (Maastrichtian)

This formation encompasses massive thick bedded argillaceous limestone and chalk with plenty of foraminiferal fauna (Ghorab 1961). Its planktonic foraminiferal taxa indicate Maastrichtian age due to the presence of *Globotruncana aegyptiaca* and *Gansserina gansseri* zones. The formation unconformably overlain by Esna Shale marks the erosional unconformity between the Cretaceous and the Paleogene times (IHS E 2006; Philobos et al. 2013; Salman 2017).

In the present work, similar to the Brown limestone unit, the Sudr Chalk is recorded in all the studied wells except RB-C1 well; this is due to the continuing of the uplift movement. It measures about 110 m and 74 m in RB-B1 and EE85-2 wells, respectively (Figs. 5 and 7).

Sequence Stratigraphic Analysis

The examined succession of the Upper Cretaceous in the study area can be subdivided into five depositional sequences of the third order (SQ-1 to SQ-5), which are punctuated by six sequence boundaries (SB1 to SB6) based essentially on the biostratigraphic report besides the well logging data (Figs. 5–8).

Sequence-1 (SQ-1)

It comprises both the Raha and Abu Qada formations belonging to the Cenomanian to early Turonian age. SQ-1 rests on SB1 and is topped by SB2 of the examined sequence. The SB1 was detected from the log's responses by the sudden increase in gamma ray log reading and the sudden decline in density log reading that characterize the transition from the non-marine Nubia Sandstone to the marine sandstone and limestone interbeds of the overlying Raha Formation. Additionally, Alsharhan (2003) documented a disconformity break. The SB2 is recognized by the sudden reduction in the density (DT) and gamma ray readings as well as sudden

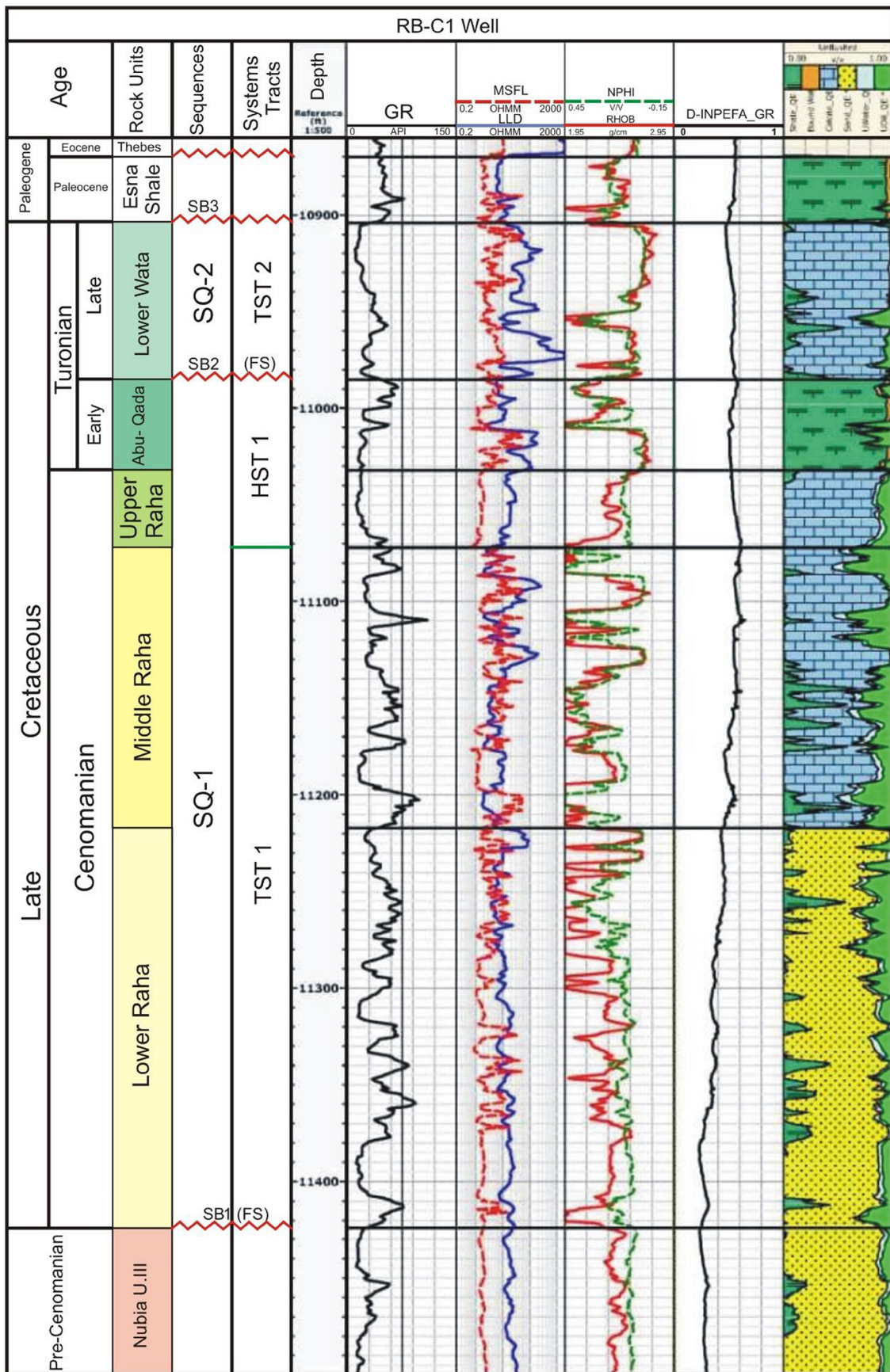


Fig. 6 Sequence stratigraphic classifications of the Upper Cretaceous section at RB-C1 borehole

increase in the density log reading, indicating the transition from the Abu Qada Formation section (mixed clastic/carbonate) to the overlying succession of the Wata Formation limestone. This sequence includes TST-1 and HST-1 and lacks lowstand deposits (Figs. 5–8).

The deposits of TST-1 are mainly composed of sandstone intercalated by shale at the base, which turns upward to be limestone beds that are accumulated under inner to outer shelf. The TST-1 covers the lower-middle Raha Formation and attains a thickness of about 142 m, 117 m, and 123 m in RB-B1, RB-C1, and EE85-2 wells, respectively (Figs. 5–7). The boundary between the TST-1 and HST-1 of the present sequence is defined by a distinct maximum flooding surface (MFS) corresponding to the highest gamma ray reading that is attributed to the peak shale facies (Figs. 5–7). The HST-1 is mainly composed of sandstone interbeds with shale and argillaceous limestone sediments that are accumulated under middle shelf condition. It displays a decline in gamma ray readings. It covers the upper Raha and Abu Qada formations and has a thickness of about 43 m and 28 m in RB-B1 and RB-C1 wells (Figs. 5 and 6).

Sequence-2 (SQ-2)

The sequence (SQ-2) includes the late Turonian Wata Formation, and its base and top boundaries are delineated by SB2 and SB3, respectively. The latter sequence boundary was characterized by sudden increase in DT and gamma ray readings, joined with a rapid decrease in the density log response, showing the alteration from the Wata Formation (mixed succession of clastic and carbonate) to the overlying Matulla Formation (sandstone succession). Also, there is a disconformity between the Wata and Matulla formations (Alsharhan 2003). SQ-2 is subdivided into TST-2 and HST-2 systems tracts as follows:

TST-2 corresponds to the lower section of the sequence-2 because the lowstand deposits are absent. TST-2 consists of shale interbedded with minor limestone that was deposited in an outer shelf condition and displays a high response of the gamma ray log. It covers the lower-middle Wata Formation and ranges about 76 m and 27 m in RB-B1 and RB-C1 wells, respectively (Figs. 5–6). The MFS at top of TST-2 is characterized by increasing gamma ray readings that are attributed to increasing shale facies content. The HST-2 comprises limestone intercalated with minor shale and sandstone that was accumulated under an inner shelf condition. It covers the upper part of the Wata Formation. The HST-2 system tract attains a constant thickness of about 51 m in RB-B1 and EE85-2 boreholes as indicated by Figs. 5 and 7.

Sequence-3 (SQ-3)

The sequence (SQ-3) contains the Matulla Formation of Coniacian–Santonian age. It emerged in RB-B1 and EE85-2

wells. The SQ-3 is placed between SB3 at the base and SB4 at the top. The SB4 was recognized by the sudden changes in responses of the gamma ray, DT, and density logs that coincide with the contact between the Matulla Formation and the overlying Brown limestone (Figs. 5 and 7). SQ-3 consists of LST-3, TST-3, and HST-3 systems tracts.

This sequence started with LST-3 that is composed mainly of sandstone deposits accumulating in an inner shelf setting. The gamma ray and DT readings of this systems tract range from low to moderate values. It covers the lowermost part of the Matulla Formation and has a thickness that ranges from 3 m in RB-B1 well to 17 m in EE85-2 well. It is followed by a gradual increase in gamma ray and DT values representing a rise of sea level. This is interpreted as a transgressive systems tract (TST-3). The TST-3 is composed of shale and limestone intercalations with sandstone which were deposited in an outer shelf environment. Its thickness ranges from 27 to 60 m in RB-B1 and EE85-2 wells, respectively. The maximum rise in gamma ray readings that corresponds to the highest increase in shale content could be attributed to the MFS (Figs. 5 and 7). The HST-3 comprises limestone intercalated with sandstone that was accumulated under middle shelf condition. It displays low to moderate readings of the DT and gamma ray logs. Its thickness is 8 and 15 m in RB-B1 and EE85-2 boreholes, respectively.

Sequence-4 (SQ-4)

The sequence comprises the Campanian Brown limestone and is recognized in the boreholes RB-B1 and EE85-2 (Figs. 5 and 7). This sequence is delineated at its lower boundary by SB4 and at its upper boundary by SB5. Top boundary is marked by the turnover lithofacies from sandstone (HST-3) to limestone (TST-4) representing a high in gamma ray and DT values. Also, it coincides with the formational contact Brown limestone/Sudr denoting a stratigraphic break due to the missing of the latest Campanian *G. calcarata* zone (IHS E 2006). The SB5 coincides with the disconformity contact given by Salman (2017) and Obaidalla et al. (2017) at the Eastern Desert as well as Obaidalla et al. (2020) at the Western Desert, Egypt.

The retrogradational deposits of TST-4 represent the base of SQ-4 and are characterized by moderately high response of the gamma ray log because the lowstand deposits are absent. These deposits include limestone interbedded with calcareous shale, which were accumulated in outer shelf conditions and have a thickness of 18 and 56 m in RB-B1 and EE85-2 boreholes, respectively. The HST-4 sediments are dominated by argillaceous limestone indicating an inner-middle shelf setting. The gamma ray response of the HST-4 deposits varies from low to moderate values, while the density log response is high. The encountered thickness of HST-4 varies between about 8 and 17 m in RB-B1 and EE85-2 wells, respectively.

Sequence-5 (SQ-5)

The sequence occupies the Sudr Chalk of the Maastrichtian age that occurred in RB-B1 and EE85-2 boreholes as shown in Figs. 5 and 7. This sequence is delimited at its lower surface by SB5 and its upper surface by SB6 (K/T boundary). The SB6 is marked by a turnover in the responses of gamma ray and DT logs, which coincide with the lithofacies alternation from the Sudr Chalk to the Esna Shale. Also, it matches with the Cretaceous/Paleogene boundary given by El-Younsy et al. (2017), Obaidalla et al. (2017, 2020), and Faris et al. (2018) as documented by a stratigraphic disconformity. SQ-5 includes TST-5 and HST-5 systems tracts and lacks the lowstand deposits.

The deposits of TST-5 cover two thirds of Sudr Chalk (lower and central parts). They are composed of chalky limestone rich in foraminiferal fauna that was deposited under outer shelf environment and coincides with a rise in sea level (Haq et al. 1987). The thickness of TST-5 is about 87 m and 58 m in RB-B1 and EE85-2 wells. The HST-5 consists mainly of argillaceous limestone, and its deposits accumulate in a middle shelf condition. It has a thickness that ranges from 23 to 16 m in RB-B1 and EE85-2 wells, respectively.

Depositional Evolution

Sequence stratigraphic investigation for the Late Cretaceous succession in Ras Budran field has exposed that this section can be subdivided into five third-order depositional cycles (Figs. 5–8). These cycles began with Cenomanian–Early Turonian cycle (SQ-1) overlain by the Late Turonian cycle (SQ-2). Moreover, the third sequence (SQ-3) represents the Coniacian–Santonian time span, and the fourth one (SQ-4) displays the Campanian time interval, while the uppermost sequence (SQ-5) was deposited during the Maastrichtian time.

The depositional evolution according to the abovementioned analysis for the examined Late Cretaceous sequence in the study area is outlined as follows:

- 1- In Cenomanian age, a major marine transgression submerged the northern portions of Egypt (Said 1990) resulting in an increase in the accommodation space above these terrains containing the area of study. These settings led to the deposition of the lower-middle Raha Formation under inner to outer shelf conditions representing the lowermost transgressive systems tract (TST-1).
- 2- By continuous basin filling with sediments during the rest of Cenomanian together with the Early Turonian times, a continuous decrease of the accommodation space happened which led to the deposition of the upper Raha Formation together with the deposition of the whole Abu Qada Formation under middle shelf conditions creating the basal highstand systems tract (HST-1) in the examined area.
- 3- By the final stages of the early Turonian time, another marine transgression took place causing an increase in the depositional space resulting in the deposition of lower-middle Wata Formation in an outer shelf condition representing the transgressive systems tract (TST-2) in the second depositional sequence. When the depositional rate increased, a stage of gradual relative sea level fall started, which led to the development of the overlying highstand systems tract (HST-2) of the upper part of Wata Formation.
- 4- During the Coniacian–Santonian times, the study area witnessed a deposition of a complete depositional cycle (SQ-3) forming the entire body of the Matulla Formation. This sequence started with a decrease in the accommodation space to the inner shelf water depth which resulted in the deposition of the lowermost parts of the Matulla Formation as lowstand systems tracts (LST). This was followed by a transgressive phase, and as a result, relatively deeper marine deposits (outer shelf sediments) were developed as TST-3 creating the middle part of the Matulla Formation.
- 5- By the final basin filling, a notable drop of the holding accommodation space took place associated with the deposition of the uppermost parts of the Matulla Formation as highstand systems tracts (HST-3).
- 6- By the Campanian age, a new depositional sequence started by a distinctly fast basin subsidence linked with deep marine invasion covering most parts of the northern Egypt (Sarhan 2017). This led to the depositing of the lower and middle parts of the Brown limestone under outer shelf conditions representing transgressive systems tracts (TST-4).
- 7- At the end of Campanian cycle, the uppermost parts of the Brown limestone were deposited as HST-4 within slow and gradual relative sea level drop (middle shelf) finishing the deposition of SQ-4.
- 8- By the Maastrichtian age, the extensive sea level rise continued with obvious increase in the depositional accommodation space and led to the deposition of the basal and middle portions of the Sudr Chalk thus forming the TST-5. This was followed by a continuous filling for the available accommodation space with carbonate sediments and led to water depth shifting from outer shelf to middle shelf, accordingly the deposition of the uppermost parts of the Sudr Chalk as highstand systems tracts (HST-5).
- 9- During the final stages of the Maastrichtian times, worldwide tectonic event took place before the deposition of the Paleogene rock units (K/Pg boundary) forming an uplifting for the pre-existing sedimentary succession associated with extensive erosional phase (Sarhan 2017).

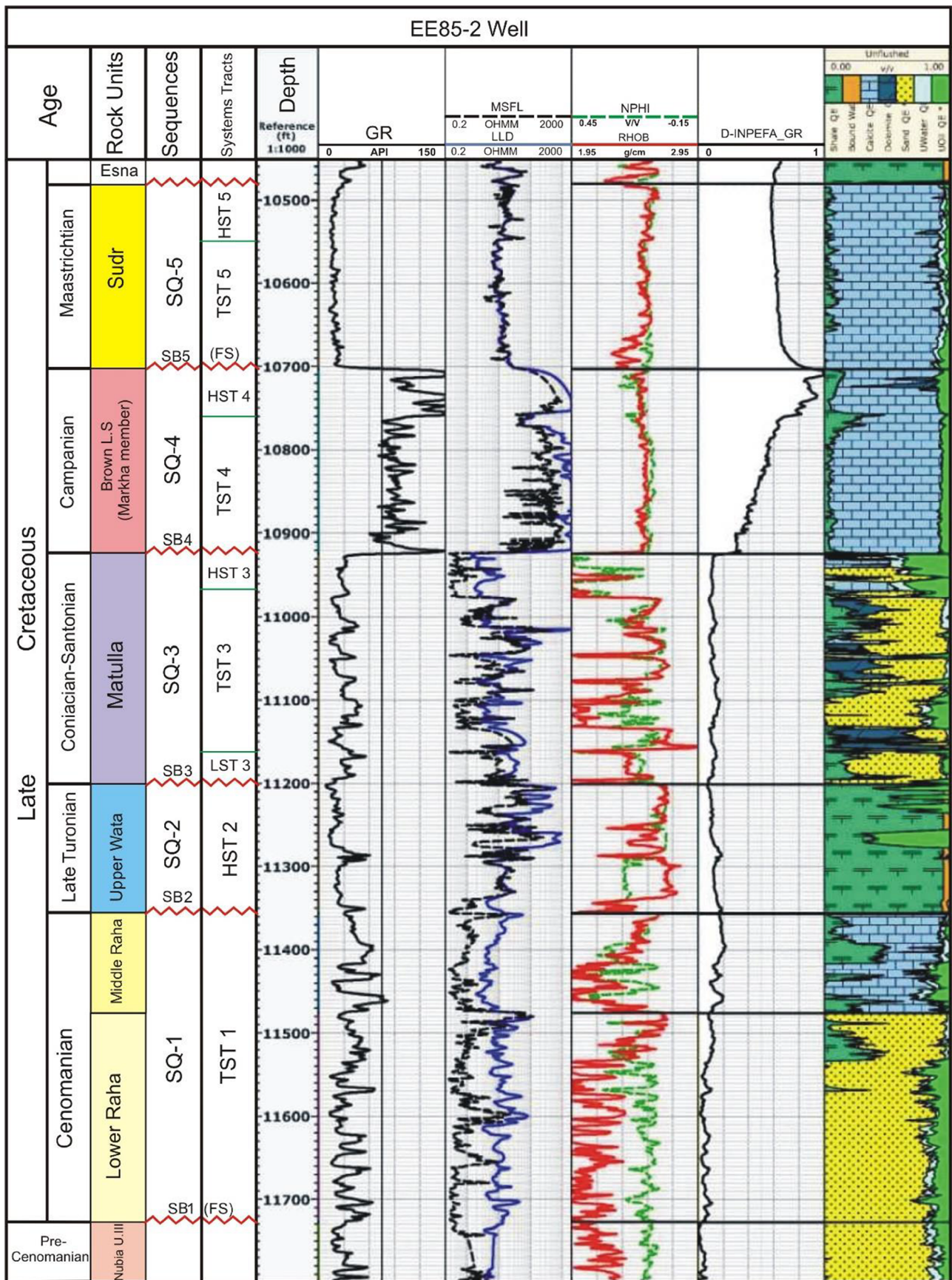


Fig. 7 Sequence stratigraphic classifications of the Upper Cretaceous section at EE85-2 borehole

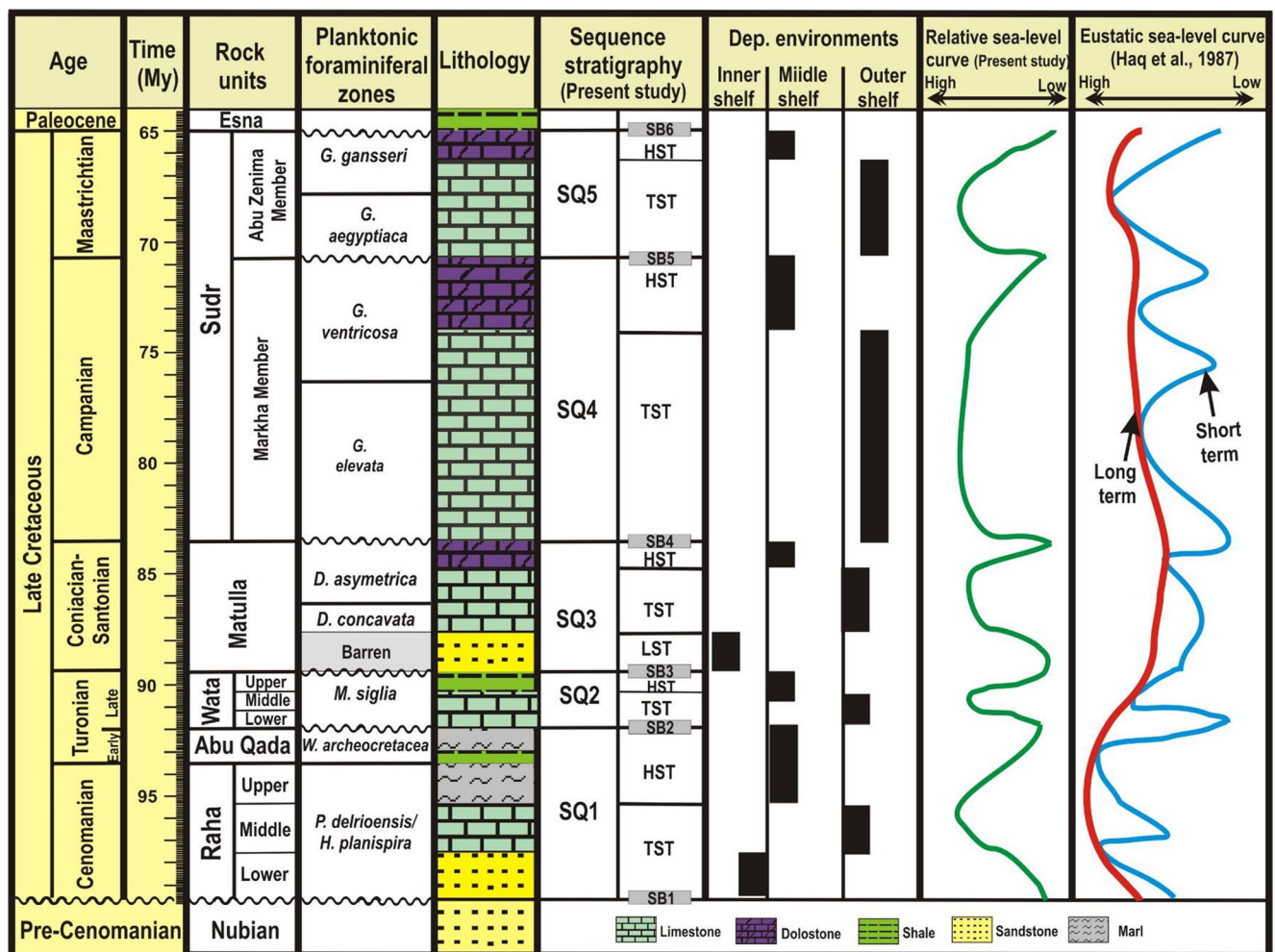


Fig. 8 Interpretation of the sequence stratigraphic framework and the proposed curve of the relative sea level of the current study correlated with the global sea level curve reported by Haq et al. (1987)

Therefore, sequence boundary of type-1 (SB6) was formed former to the deposition of the superimposing Paleogene strata and finishing the depositional story of the Upper Cretaceous section in Ras Budran Ffield.

Conclusions

The investigated Upper Cretaceous deposits in the study area have been classified into five third-order depositional sequences. The first depositional sequence (SQ-1) comprises of Raha and Abu Qada formations (Cenomanian–early Turonian). The second depositional sequence (SQ-2) encompasses the late Turonian Wata Formation that is composed of carbonate deposits at the base deposited during the gradual progress of the sea level rise. The third depositional sequence (SQ-3) includes the Coniacian–Santonian Matulla Formation, which is characterized by shallow clastic sediments deposited during the low sea level phase. The fourth depositional

sequence (SQ-4) coincides with the Campanian Brown limestone, which is characterized by deeper carbonate sediments upward to shallow one. The fifth depositional sequence (SQ-5) contains the Maastrichtian Sudr Chalk that initiates with transgressive carbonate sediments and ends with regressive deposits.

The Late Cretaceous depositional evolution along Ras Budran field was characterized by a continuous change in relative sea level during the deposition of the entire depositional cycles. The increase in the accommodation spaces (i.e., the rising in relative sea level) was affected by the real sea level rising joined with the fast basin subsidence, while the drop in the accommodation space intervals was controlled by the basin filling status. As a result, the local sea level of the Upper Cretaceous deposits in the study area which are deduced from their lithofacies and biofacies aspects as well as logs variations is consistent with long-term eustatic sea level, but it differs or does not totally match with the short-term eustatic sea level due to the impact of local tectonics (Syrian Arc System). Hence, the Ras Budran oil field is a product of

the combined effect of global sea level and/or local tectonic activity in the region.

Acknowledgements The authors thank the Egyptian General Petroleum Corporation (EGPC) and Suez Oil Company (SUCO), for supplying the data for this study. Also, deep grateful to the Editor-in-Chief (Prof. Abdullah M. Al-Amri), the guest Editor for the Special Issue SCJGE-1 (Prof. Zakaria Hamimi) and the anonymous reviewers for their valuable and critical comments.

Declarations

Conflict of interest The authors declare that they have no competing interests

References

- Al Naggar A, Helaly H (1985) Geological aspects and reservoir units, Ras Budran Field, eighth production seminar. E.G.P.C, Cairo-Egypt
- Al-Areeq NM, Elhossainy MM, Salman AM (2020) Sequence stratigraphic architecture of the Upper Jurassic-Lower Cretaceous deposits in the Sayun-Masilah Basin, Yemen: a case study from Masilah oilfields. *J Asian Earth Sci* 192:104287. <https://doi.org/10.1016/j.jseas.2020.104287>
- Alsharhan AS (2003) Petroleum geology and potential hydrocarbon plays in the Gulf of Suez rift basin, Egypt. *Am Assoc Petrol Geo Bull* 87: 143–180
- Atia HM (2014) An integrative modeling of Ras Budran Field, Gulf of Suez, Egypt. M.Sc Thesis. Department of Geology, Mansoura University, Egypt 198 p.
- Atia HM, Ahmed AM, Korrat I (2015) Thermal maturation simulation and hydrocarbon generation of the Turonian Wata Formation in Ras Budran oil field, Gulf Of Suez, Egypt. *J Environ Sci* 44(1):57–92
- Awad MH, Serag El Din S (2009) Micro-zonation and characterization of the pre-Miocene reservoirs in Ras Budran oil field, Gulf of Suez, Egypt. *J Geol Mining Res* 1(9):180–194
- Bauer J, Marzouk A, Steuber T, Kuss J (2001) Lithostratigraphy and biostratigraphy of the Cenomanian–Santonian strata of Sinai, Egypt. *Cretac Res* 22:497–526
- Bauer J, Kuss J, Steuber T (2003) Sequence architecture and carbonate platform configuration (late Cenomanian–Santonian), Sinai, Egypt. *Sedimentology* 50:387–414
- Catuneanu O (2006) Principles of sequence stratigraphy. Elsevier, Amsterdam
- Catuneanu O, Abreu V, Bhattacharya JP, Blum MD, Dalrymple RW, Eriksson PG, Fielding CR, Fische WL, Galloway WE, Gibling MR, Giles KA, Holbrook JM, Jordan R, Kendall CG, Macurda B, Martinsen OJ, Miall AD, Neal JE, Nummedal D, Pomar L, Posamentier HW, Prat BR, Sarg JF, Shanley KW, Steel RJ, Strasser A, Tucker ME, Winker C (2009) Towards the standardization of sequence stratigraphy. *Earth Sci Rev* 92:1–33
- Chowdhary LR, Taha S (1987) Geology and habitat of oil in Ras Budran field, Gulf of Suez, Egypt. *Am Assoc Petrol Geo Bull* 71(10):1274–1293
- Chowdhary LR, Shaheen S, Naggar AA (1986) Structure and structural evolution of Ras Budran, Gulf of Suez, Egypt. Eighth Exploration Seminar, Cairo.
- El-Gendy NH, Barakat MK, Abdallah H (2017) Reservoir assessment of the Nubian sandstone reservoir in South Central Gulf of Suez-Egypt. *J Afr Earth Sci* 129:596–609. <https://doi.org/10.1016/j.jafrearsci.2017.02.019>
- El-Younsy AR, Obaidalla NA, Philobos ER, Salman AM (2017) High-resolution sequence stratigraphy of the Upper Cretaceous-Lower Paleogene succession, Gabal Qreiya area, Upper Egypt. *Arab J Geosci* 10:531
- Emery D, Myers KJ (1996) Sequence stratigraphy. Blackwell, Oxford, 297p
- Faris M, Obaidalla NA, Metwally A, Salman MA, Zaky A (2018) Late Cretaceous–Early Paleogene tectonic events at Farafra-Abu Minqar Stretch, Western Desert, Egypt: results from calcareous plankton. *Arab J Geosci* 11:429
- Ghorab MA (1961) Abnormal stratigraphic features in Ras Gharb oil field. 3rd Arab Petrol Congr: 1–10
- Goldhammer RK, Dunn PA, Hardie LA (1990) Depositional cycles, composite sea-level changes, cycle stacking patterns, and the hierarchy of stratigraphic forcing: examples from Alpine Triassic platform carbonates. *Geol Soc Am Bull* 102:535–562
- Haq BU, Hardenbol J, Vail PR (1987) Chronology of fluctuating sea levels since the Triassic. *Science* 235:1156–1167
- IHS E (2006) Gulf of Suez basin monitor (No. Iris21 ID: 410900. IHS Energy).
- Koldewijn B W (1984) Sedimentological investigations of Nubian sandstone cores—Ras Budran field: SUCO internal company report.
- Kuss J, Scheibner C, Gietl R (2000) Carbonate platform to basin transition along an Upper Cretaceous to Lower Tertiary Syrian Arc uplift, Galala Plateaus, Eastern Desert, Egypt. *Geo Arabia* 5:405–424
- Mandour MM, Baioumi AA (2009) Stratigraphical and paleoecological studies on Upper Cretaceous succession of Gs 160-2 well, Gulf of Suez, Egypt. *J Appl Sci Res* 5(12):2247–2261
- Mohsen S, Zein El-Din YM, Taher M (1975) An outlook of the geology of the Zeit Basin and its oil prospects. The 9th Arab Petroleum Congress, Dubai 1- 13.
- Moller A (2001) Ras Budran petrophysical and petrographical characterization of core samples. SUCO Internal Report
- Moon FW, Sadek H (1923) Preliminary geological report on Gebel Khoshera area (West Sinai). *Review Petrol Res Bull* 9:1–40
- Nabawy B, Barakat MK (2017) Formation evaluation using conventional and special core analyses: Belayim Formation as a case study, Gulf of Suez, Egypt. *Arab J Geosci* 10(25):1–23
- Obaidalla NA, El-Younsy AR, Philobos ER, Salman AM (2017) Impact of the African/Arabian and Eurasian plates collision on the evolution of the Upper Cretaceous-Lower Paleogene Sedimentary Basin, Eastern Desert, Egypt. *Int J Ecol Sci Environ Eng* 4(5):51–71
- Obaidalla NA, El-Sheikh I, Mahfouz K, Salman AM, Soliman MF, Abdel-Aleem FM (2020) Upper Cretaceous–lower Paleocene subsurface sequence, Farafra Oasis, Western Desert, Egypt: stratigraphical and paleoenvironmental inferences. *Arab J Geosci* 13:957. <https://doi.org/10.1007/s12517-020-05812-x>
- Philobos ER, Obaidalla NA, El-Younsy ARM, Salman AM (2013) Biostratigraphically-, and sedimentologically-based sequence stratigraphy of the Campanian-Eocene succession of Wadi Tarfa-north Wadi Qena area, north Eastern Desert, Egypt. The 13th Annual Meeting of the Paleontological Society of Egypt:13–17
- Posamentier HW, Allen GP (1999) Siliciclastic sequence stratigraphy: concepts and application. *SEPM Concepts in Sedimentology and Paleontology* No.7: 210 p.
- Rose J, Askary S, Andriani M (1985) Ras Budran field petrophysical study and core correlation: Eighth Production Seminar, Cairo, Paper RF/25.
- Said R (1962) The geology of Egypt. Elsevier, Amsterdam, p 377
- Said R (1990) Geology of Egypt. Rotterdam, Balkema 743 p.
- Salman AM (2017) Sequence stratigraphy and sedimentology of some Upper Cretaceous - Lower Paleogene successions in Upper Egypt. PhD Thesis Fac Sci Assiut Univ, Egypt:189p
- Sarhan MA (2017) Seismic-wireline logs sequence stratigraphic analyses and geologic evolution for the Upper Cretaceous succession of Abu Gharadig basin, Egypt. *J Afr Earth Sci* 129:469–480

- Shahin A, Kora M (1991) Biostratigraphy of some Upper Cretaceous successions in the eastern central Sinai, Egypt. *N Jb Geol Palaont Mh* 11:671–692
- Van Wagoner JC, Mitchum Jr, Campion KM, Rahmanian VD (1990) Siliciclastic sequence stratigraphy in well logs, core, and outcrops: concepts for high-resolution correlation of time and facies. *Am Assoc Petrol Geo Methods Exploration Series* 7:1–55
- Zein El-Din MY, Taher M (1973) In contribution of dipmeter analysis to the history of West Gable El-Zeit basin, Gulf of Suez. 11th Annual Meeting of the Geological Society of Egypt, Cairo.