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Seismic Facies Interpretations and Depositional Sequences of the Cretaceous Sediments in Beni Suef Basin, Nile Valley, Egypt

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Abstract: *The Beni Suef Basin is a petroliferous rift basin straddling the River Nile including a thick Mesozoic–Paleogene succession. It is bisected by the major course of the River Nile Valley into two provinces; West of Nile province (WON) and East of Nile province (EON). The Cretaceous succession in Beni Suef Basin can be subdivided into two main megasequences; Lower Cretaceous Megasequence and Upper Cretaceous Megasequence. Seismically, the Lower Cretaceous Megasequence comprises two seismic facies and displays a general sheet-like to wedge-shaped geometry. It includes seismic facies displaying chaotic to parallel reflector configuration with variable continuities and amplitudes. The Upper Cretaceous Megasequence displays a general external form of giant sheet geometry. It comprises seven seismic facies varying between sub-parallel to uniform parallel reflector configurations with variable continuities and amplitudes. The integration between the seismic facies and well-logging datasets enabled the subdivision of the Cretaceous sediments into seven 3rd order depositional sequences (DSQ-1 – DSQ-7) and an uppermost 2nd order sequence (DSQ-8) with definite boundaries (Sb-1 – Sb-9 The depositional interpretations of the encountered seismic facies in both megasequences are discussed and the progressive depositional evolution of the concluded depositional sequences is interpreted. Accordingly, the Lower Cretaceous Megasequence was developed as fluvial-to-deep shelf sedimentary body, whereas the Upper Cretaceous Megasequence is a widespread sedimentary body that was developed under fluctuating shallow-to-deep shelf marine settings, and ended by open marine to outer shelf conditions. The deposition of both megasequences was intermittently overprinted by several episodes of the local and regional tectonic events influenced the area.*

Keywords: *Beni Suef Basin, Cretaceous seismic facies analysis, depositional sequences*

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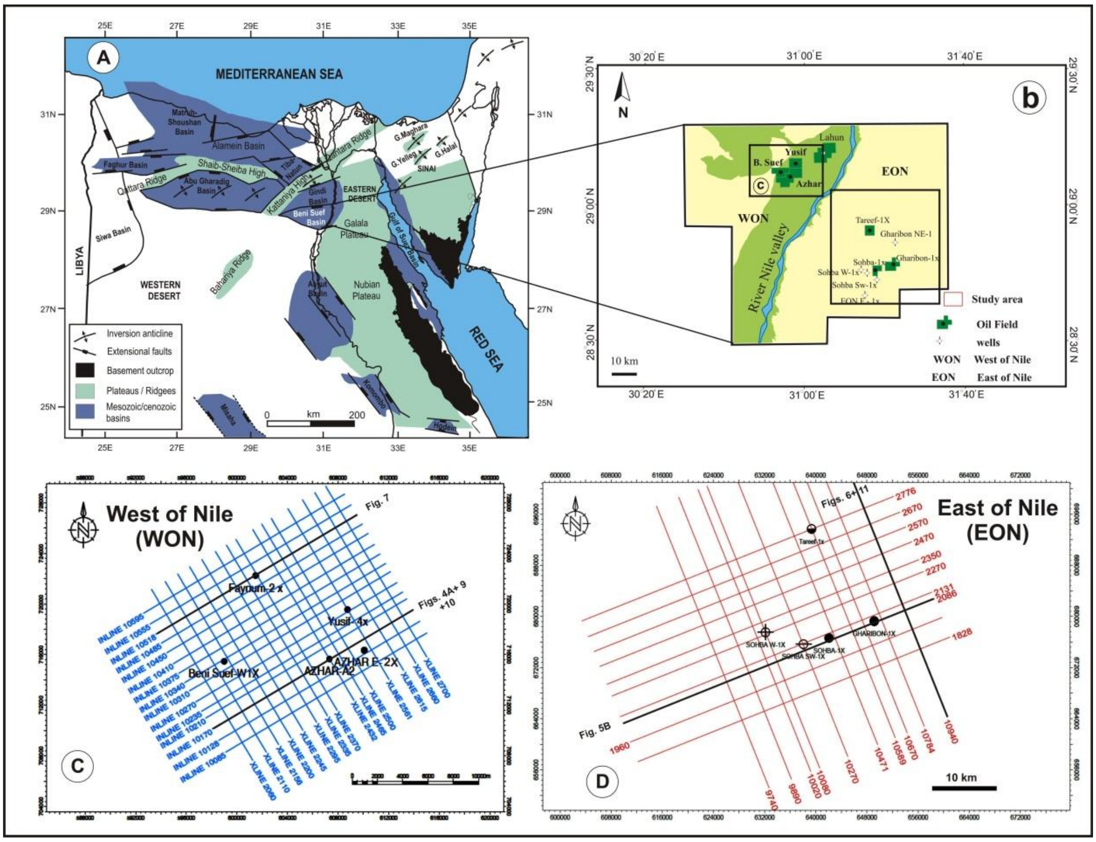
I. Introduction

The Beni Suef Basin is one of the promising areas, newly considered in the future plan of hydrocarbon potentialities in Egypt. It is situated in the vicinity of some well explored basins at the northern part of the Western Desert and Nile Valley (viz.: Gindi basin, Abu Gharadig basin, Asyut basin, etc., Fig. 1A). The Basin lies in North Central Egypt at ~ 150 km south of Cairo. It extends between the latitudes 29° 25' 50" and, 28° 31' 33.797 " N and the longitudes 31° 30' 51.372" and, 29° 50' 7.779" E (Fig. 1). Topographically, the area is characterized by a low-land surface, and the basin itself is bisected by the major course of the River Nile and its valley into two provinces; West of Nile province (WON) and East of Nile province (EON), (Fig. 2B).

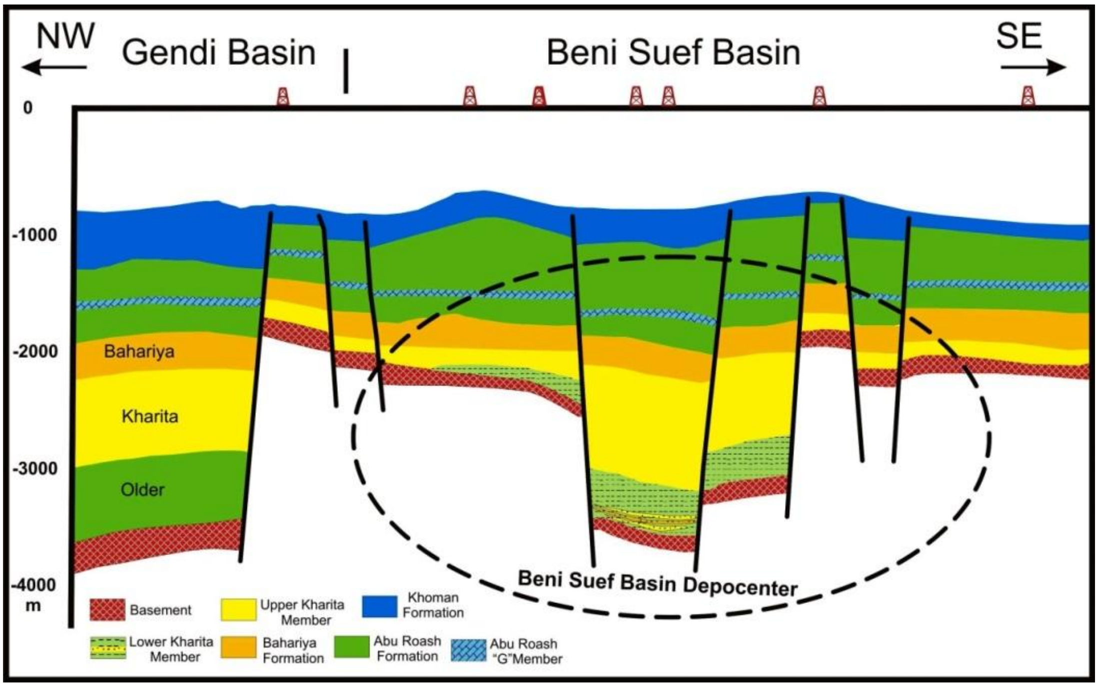
The depocenter of Beni Suef Basin is located at the Azhar-A2Well (WON) that has the maximum accumulated stratigraphic thickness up to ~ 4000 m, having a complete stratigraphic succession of the Early Cretaceous (Albian) Kharita Formation (Fig. 2). The Beni Suef Oil Field was discovered by Seagull Energy Corporation, and then Qarun Petroleum Company has developed the field by digging five oil wells: Azhar, Yusif, Gharibon, Lahun and Sobha.

Seismic facies analysis is essential for seismic interpretation workflow where much information on depositional process, sedimentary environment and ultimately reservoir potential can be determined from seismic data ([1]; [2]; [3]).

The present work aims to use the seismic and well-logging datasets of the subsurface Cretaceous sedimentary succession of the Beni Suef Basin to deduce the present seismic facies and interpret their depositional settings. Moreover, the integration of the seismic and well-logging datasets will be utilized to discuss the overall depositional sequence framework of the examined succession.



(Fig. 1): (A) Mesozoic and Cenozoic Basins in Egypt (modified after [5]; [6]; [7]; [8]). (B) Location map of Beni Suef Concession with the study area. (C & D) Index maps showing the studied seismic lines and wells in the WON and EON respectively.



(Fig. 2): Regional geological cross section trending NW-SE passing throw Beni Suef Basin. (Modified after, [9])

II. Datasets, Methods and Technique

This study is based on the analysis of the seismic and well log data of the basin fills. This analysis was carried herein using fifty seismic profiles, extracted from (3D) survey; thirty in the West of Nile province (WON) in depth domain (Fig. 2C) and twenty in the East of Nile Province (EON) in time domain (Fig. 2D).These seismic profiles cover the study area (1900 km^2) of both provinces (EON and WON) of Beni Suef Basin. In addition, the well-log data of ten deep wells were examined for precise interpretation of both facies and depositional sequences. These well-log data belong to the wells: Azhar- A2, Azhar E-2X, Beni Suef West-1X, Yusif-4X and Fayoum-2X from the western province (WON), and Tareef-1X, Gharibon-NE-1, Gharibon-1X, Sohba-1X, Sohba-W1X, Sohba-SW 1X, and EON F-1X from the eastern province (EON). The well-logs include mud logs, gamma ray, resistivity, photoelectric, porosity, sonic logs and litho-composite logs. The seismic profiles and well-logs were kindly provided by the Qarun Petroleum Company with permission of The Egyptian General Petroleum Corporation (EGPC).

The detailed investigations of the available reflection configurations, continuity and amplitude within the entire seismic interval have enabled subdivision the examined succession into several successive seismic facies; each is characterized by definite seismic characteristics related to a specific depositional setting according to the fundamentals of [4], [1], [2] and [3]. Also, the discussion of the well-logging data will help delineating the sequence boundaries that are not clear in the seismic profiles or to confirm the clear boundaries in the seismic lines to define the depositional sequences forming the Cretaceous succession in the given basin.

III. Geologic and lithostratigraphic framework

The Beni Suef Basin is considered as one of a series of intra-continental rift basins straddling the River Nile such as the Komombo and Asyut basins (Fig. 1A) whose evolution was proposed to be linked with breakup of the Western Gondwana and the opening of the South and Equatorial Atlantic Ocean during the Late Jurassic-Early Cretaceous ([6], [7] and [8]).The basin has a relatively thick subsurface Mesozoic–Tertiary sedimentary cover of six rock units (Fig. 3), namely from base to top as; Kharita Formation (Early Cretaceous, Albian), Bahariya Formation (Early Cenomanian), Abu Roash Formation (Late Cenomanian-Santonian), and Khoman Formation (Campanian–Maastrichtian) ([10]).This stratigraphic succession rests non-conformably over the crystalline basement rocks, whereas it is overlain by the Early Eocene Apollonia Formation. A brief of the lithological characteristics and depositional setting of the Cretaceous rock units in Beni Suef Basin are summarized in Table 1.

Table1: Lithological characteristics and depositional setting of the Cretaceous rock units in the Beni Suef Basin

Age		Formation / Nomenclature	Lithological characteristics	Depositional setting
CRETACEOUS	Campanian-Maastrichtian	Khoman Fm [11]	Almost clean composition of snow white chalk and chalky limestone with abundant chert bands.	Open marine to outer shelf condition ([14]).
	Late Cenomanian-Santonian	Abu Roash Fm [11] (A, B, C, D, E, F, G members	It is informally classified from base to top into; G, F, E, D, C, B & A members. This formation is mainly composed of sandstone, siltstone with shale and carbonate intercalations. Generally, the members B, D and F are relatively clean carbonates while members A, C, E and G are largely fine clastics.	Neritic to open marine conditions, except for the "G" Member that was deposited in lagoonal to middle shelf conditions ([15]). Palynological work suggests that "G" to "C" members have been deposited in inner shelf settings ([16]; [17]; [18]; [19]).
	Cenomanian	Bahariya Fm [12]	Siltstone and sandstone interbeds with minor shale and limestone streaks.	Transitional, fluvial to shallow marine (tidal flat to estuarine) settings ([20]; [21]; [22]; [19]).
	Albian	Kharita Fm [11]&[13]	Non-conformably overlies the basement rocks, divided into two members; the Lower Kharita Shale Member which consists of shale and siltstone with minor sandstone interbeds and Upper Kharita sandstone Member that is composed mainly of sandstone with minor siltstone interbeds.	Widespread continental fluvial sedimentation phase prevailed over the entire northern parts of the Western and Eastern Deserts as well as in Sinai (e.g.: [23]; [24]; [25]; [26]; [27]).

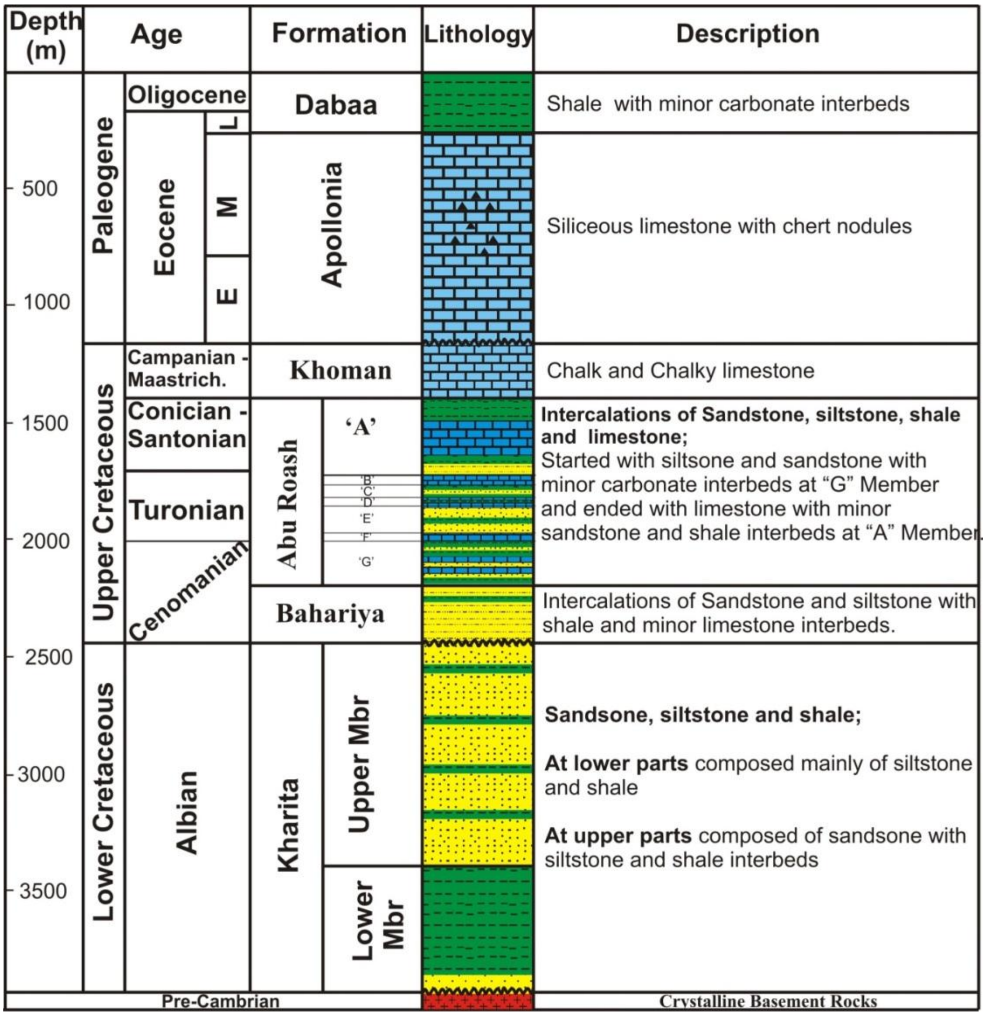


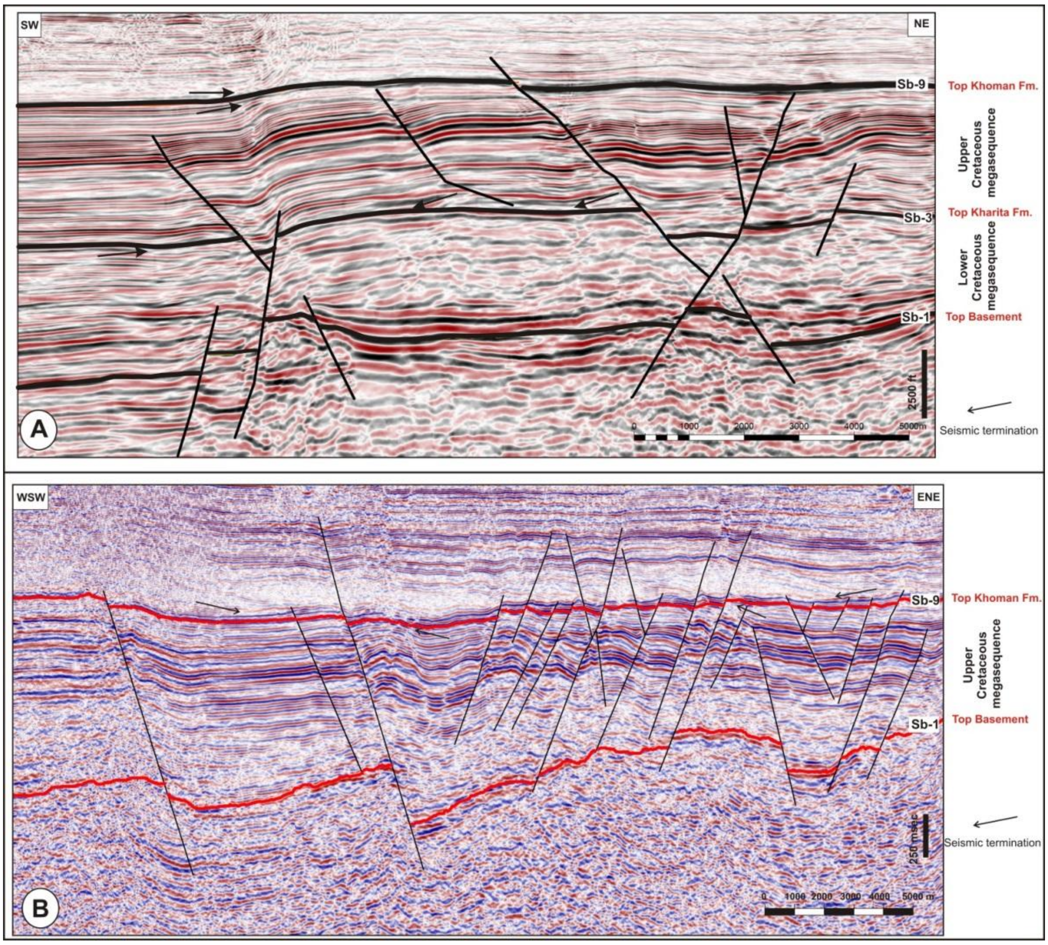
Fig. 3): Generalized lithostratigraphic units in the Beni Suef Basin (modified after, [10]).

IV. Results

4.1. Seismic Depositional Sequences:

Detailed investigation of the available seismic lines proved that the examined Cretaceous succession is composed of two main seismic megasequences (Fig. 4); a lower one of Lower Cretaceous (Albian) age and an Upper Cretaceous one of Cenomanian-Maastrichtian age. Both megasequences are encountered in the western provinces of Beni Suef basin (WON), (Fig. 5A), whereas the eastern province (EON) only comprises the younger Cenomanian-Maastrichtian megasequence (Fig. 4B).

The Early Cretaceous (Albian) Megasequence in the WON sector of the basin is bounded by two major unconformity surfaces; the lower (Sb-1) is the non-conformable contact with the Egyptian basement rocks all-over the study area, and the upper contact (Sb-3) is an unconformity surface, seismically defined due to onlapping terminations of the overlying Upper Cretaceous megasequence (Fig. 4A). On the other hand, the Cenomanian-Maastrichtian megasequence is encountered all-over the study basin. It rests non-conformably over both Sb-1 in the EON (Fig. 4B), and the unconformity surface (Sb-3) in the WON (Figs. 4A and 8). The upper contact (Sb-9) marks the top contact of the Cenomanian-Maastrichtian Megasequence (Figs. 4A and 8). It is encountered all-over the study area, representing the major K/T boundary with clear stratigraphic hiatus between the Campanian-Maastrichtian Khoman Formation and Early Tertiary Paleocene Apollonia Formation. Sb-9 is an unconformity surface, seismically marked by the onlapping terminations of the overlying Tertiary units (Fig. 4).



(**Fig. 4):** NE–SW and WSW-ENE seismic lines showing (A) the Lower and Upper Cretaceous megasequences in the WON, (B) the Upper Cretaceous megasequence in the EON. Notice the seismic terminations (Black arrows). For location see (Figs. 2C and D).

4.2. Seismic Facies:

Investigations of the reflection configurations, continuity and amplitude within the entire seismic interval enabled subdivision of the examined megasequences into several seismic facies; each is characterized by definite seismic characteristics related to a specific depositional setting. The description of these seismic facies, following the concepts of Sangree and Widmier (1979) [1], from the base to top provides the following:

4.2.1. The Seismic Facies-One (SF-1):

This seismic facies is represented by the rock interval extending from the top of the basement complex to the top of the Albian Lower Kharita Member in the western part of the study area (WON), (Fig. 5). This facies is generally composed of shale beds that regularly intercalate with siltstone, limestone and some sandstone interbeds in the lower and upper levels. Seismically, SF-1 shows uniform parallel configuration with moderate to high continuity and relatively high amplitude facies reflections. This reflects well stacked, regular depositional regime with alternative high and low energy. This assumes deposition under alternative coastal shallow marine and inner-shelf settings.

4.2.2. The Seismic Facies-Two (SF-2):

SF-2 is represented by the rock interval extending from the top of the Albian Lower Kharita Member to the top of the Albian Upper Kharita Sandstone Member in the western part of the study area (WON), (Fig. 5). This facies is generally composed of gravelly, coarse to medium grained sandstones with some siltstones intercalations. Seismically, SF-2 shows chaotic to rarely sub-parallel configuration with low to moderate continuity and variable-amplitude facies reflections.

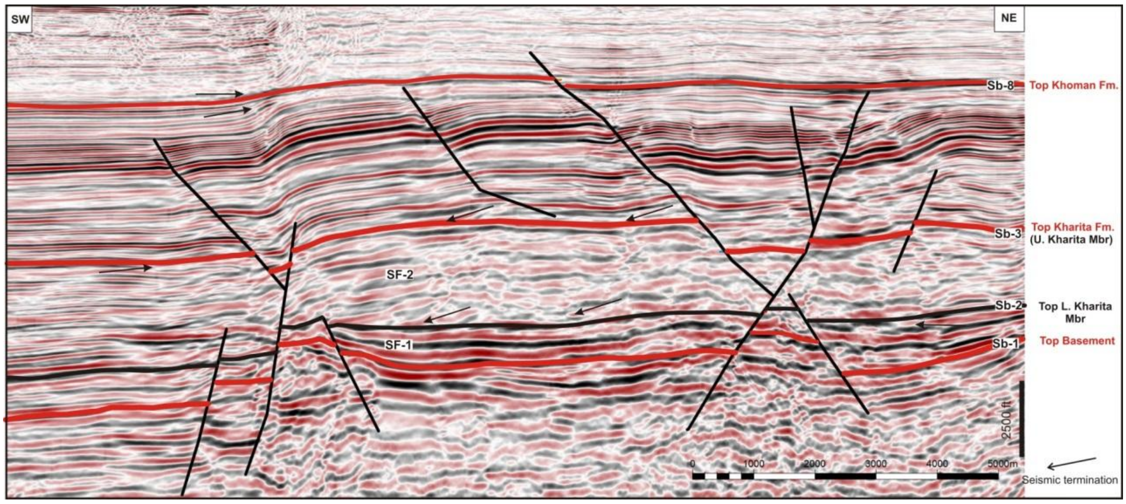


Fig. 5): NE–SW seismic line showing the seismic facies (SF-1 & SF-2) in the Lower Cretaceous Megasequence. Notice the seismic terminations (Black arrows). For location see (Fig. 2C).

This reflects deposition under high energy turbulent regimes, possibly related to effective fluvial currents (braided channels).

4.2.3. The Seismic Facies-Three (SF-3):

This seismic facies includes the rock interval of the entire Cenomanian Bahariya Formation all-over Beni Suef basin (Fig. 6). It is composed of thick succession of gravelly to coarse kaolinitic sandstones, topped by siltstone and sandstone interbeds with minor shale and limestone streaks.SF-3 is seismically represented by sub-ordinate interfering-bundles of chaotic and rarely sub-parallel configurations, irrhythmically distributed throughout the facies interval, with low to moderate continuity and variable-amplitude facies reflections. The facies reflects deposition under variable high-energy regimes disrupted by short-lived uniform depositional episodes. This indicates dominance of high energy river currents, mixed with quiet intervals of flood-plain formation. Marginal marine processes could be traced at the topmost sub-parallel to parallel configurations.

4.2.4. The Seismic Facies-Four (SF- 4):

SF- 4 represents the rock interval of the Late Cenomanian Abu Roash “G” Member (Fig. 6). It is mainly composed of shale with limestone with minor siltstone and sandstone interbeds. Seismically, SF-4 shows sub-parallel configuration with moderate continuity and low-amplitude reflectors. The facies represents uniform low-energy depositional regime within an open depositional setting, could be shallow marine platform.

4.2.5. The Seismic Facies-Five (SF-5):

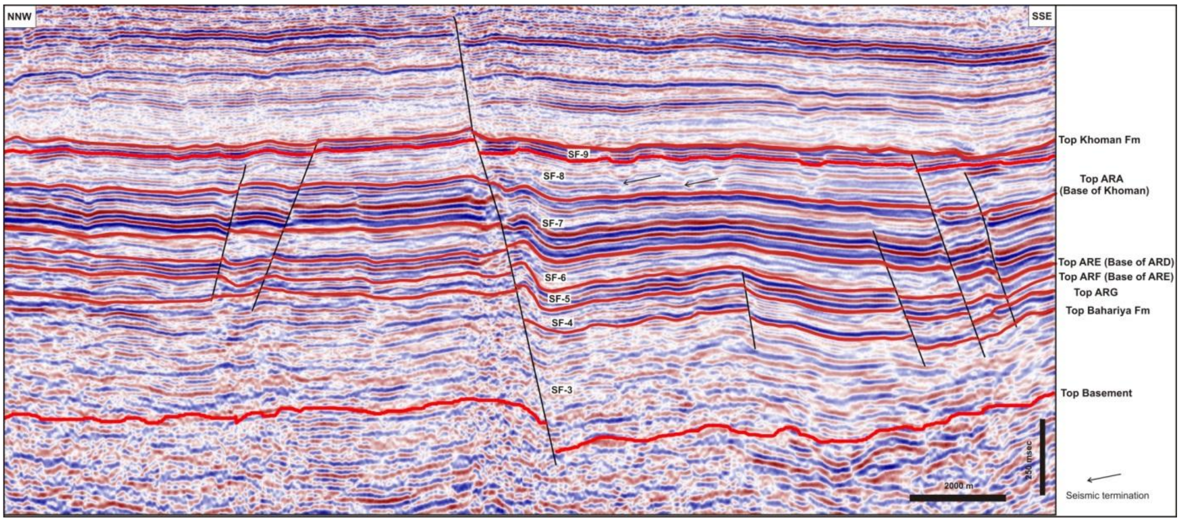
This seismic facies represents the rock interval extending from the top of Abu Roash “G” Member to the basal parts of Abu Roash “E” Member (Fig. 6). It is generally consists of successive shale and thick carbonates interbeds. This facies displays well-stacked uniform parallel configuration with moderate to high continuity and relatively high amplitude reflectors. This reflects well stacked interbeds deposited within widespread environment with uniform high and low energy conditions, mostly dominate inner – open marine shelf.

4.2.6. The Seismic Facies-Six (SF-6):

SF-6 represents the rock interval from the top of the basal parts of Abu Roash “E” Member to the basal parts of Abu Roash “D” Member (Fig. 6). It consists of kaolinitic sandstone with shale, siltstone and limestone interbeds. SF-6 shows sub-parallel to partly chaotic configuration with low to moderate continuity and variable-amplitude reflectors. This facies suggests deposition within relatively quiet uniform depositional setting, intermittently disrupted by sudden input of variable energy. Deposition within a marginal marine setting, receiving supra-crustal input is assumed herein.

4.2.7. The Seismic Facies-Seven (SF-7):

This seismic facies extends from the top of the basal part of Abu Roash “D” Member to the top of "A" Member, Abu Roash Formation (Figs. 6 and 7). It consists of a thick shale succession interbedded with sandstones, and limestone. SF-7exhibits markedly, uniform well-stacked simple parallel configuration with high continuity and high amplitude reflectors.



(**Fig. 6):** NW–SE seismic line showing the seismic facies 3 to 9 (SF-3 to SF-9). For location see (Fig. 2D).

This seismic facies represents a long-lasted deposition under alternative high and low energy conditions within a widespread depositional basin enabling the development of such laterally extensive and well-stacked interbeds. Deposition within an open marine platform setting is herein assumed.

4.2.8. The Seismic Facies-Eight (SF-8):

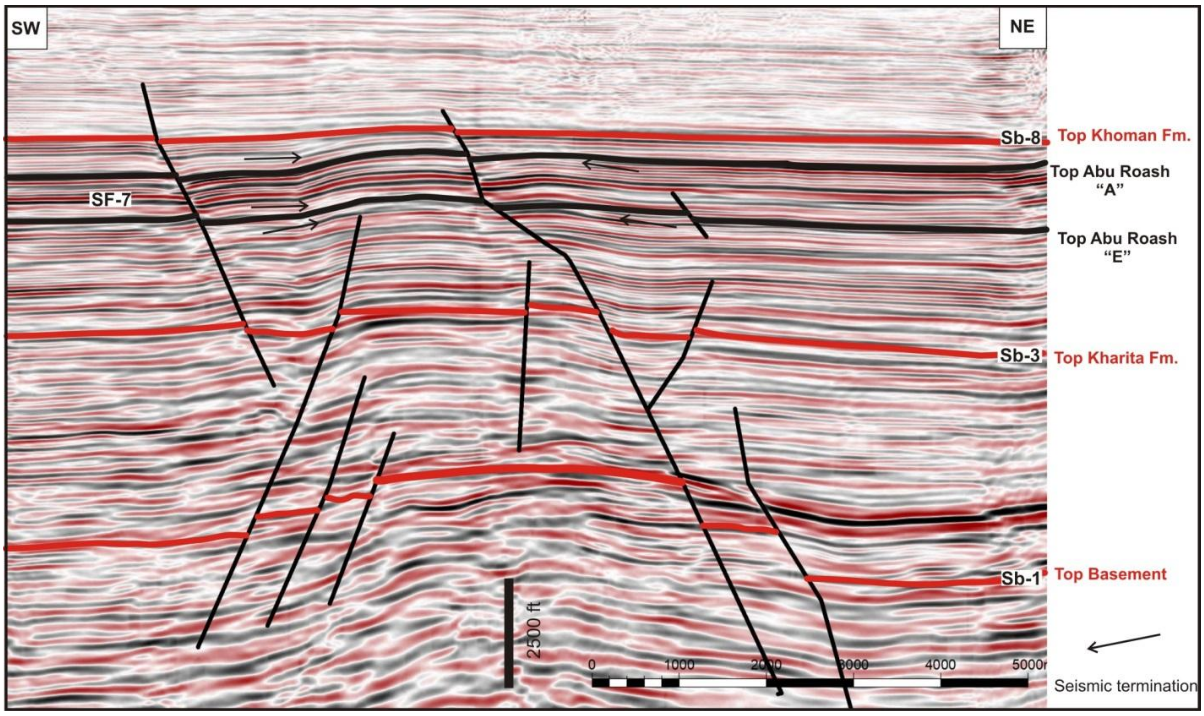
This seismic facies is represented by the rock interval extending from the top of "A" Member, Abu Roash Formation toward the upper levels of the snow white chalk sediments of Khoman Formation (Fig. 6). SF-8 shows sub-parallel configuration, with moderate to high continuity and relatively low-amplitude reflectors, indicating deposition within a basin having moderate to low energy. The seismic and lithological characters and facies overweigh deposition within a widespread outer marine basin with moderate to low energy.

4.2.9. The Seismic Facies-Nine (SF-9):

This seismic facies represents the upper-most levels of the Campanian-Maastrichtian Khoman Formation (Fig. 6) and the examined Upper Cretaceous Megasequence. SF-9 shows uniform, well-stacked simple parallel configuration, with high continuity and high amplitude reflectors. These seismic characters assume deposition under alternative high and low energy conditions within a widespread depositional basin facilitate the evolution of laterally well-stacked extensive bed-geometries. Deposition within an open shelf basin is suggested for this facies, terminating the depositional history of the Upper Cretaceous in the study area.

4.3. External form and depositional interpretation

The external form of a depositional sequence commonly expresses the general external geometry of that sequence [28].For the Lower Cretaceous Megasequence; it displays a general external form of sheet-like to wedge-shaped geometry (Fig. 4A). This external form typically characterizes wide fluvial-to-deep marine water depositional settings. In such setting, the non-marine - marine sediment types generate seismic facies having parallel reflection configurations that are gradually graded basin-ward ([1], [2], [3] and [4]). Moreover, within this depositional setting, the reflectors are concordant at the base (e.g.: through the non-conformity surface, Sb-1) and onlapped by coastal facies (e.g.: the shallow marine Bahariya Formation through Sb-3) at the top (Fig. 5A). For the Upper Cretaceous Megasequence, it displays a general external form of giant sheet geometry (Figs. 4A & B, 6 and 7). This external form typically characterizes the shelf depositional setting. In such setting, the seismic facies tend to generate parallel to gently divergent reflection configurations. In the shelf setting, the reflectors are normally concordant at the top and vary from concordant to gently onlapping and occasionally downlapping at the base (Fig. 4A and 10 A). The concordance relationship of reflectors characterizing the present shelf-megasequence explains the lack of reflection terminations necessary for sequences and system tract delineation.



(**Fig. 7):** NE–SW seismic inline showing the seismic facies 7 (SF-7). Notice the seismic terminations (Black arrows). For location see (Fig. 2C).

4.4. Depositional sequences:

The seismic facies analysis is considered as an effective method for delineating the depositional sequences in case of the presence of clear seismic terminations, otherwise the well-log data can help determination of such boundaries. The integration between the seismic and well data has a vital role in determining the sequence boundaries and defining the depositional sequences, as it is adopted herein for the examined Cretaceous megasequences. Accordingly, the Lower Cretaceous megasequence is subdivided into two 3rd order depositional sequences (Fig. 8).The Upper Cretaceous Megasequence is subdivided into five 3rd order depositional sequences and one 2nd order depositional sequence with little changes on both sides of the Beni Suef Basin (Fig. 8), following the concepts of [29].These depositional sequences are informally named as DSQ-1 to DSQ-8. The following is the discussion of each interpreted depositional sequence:

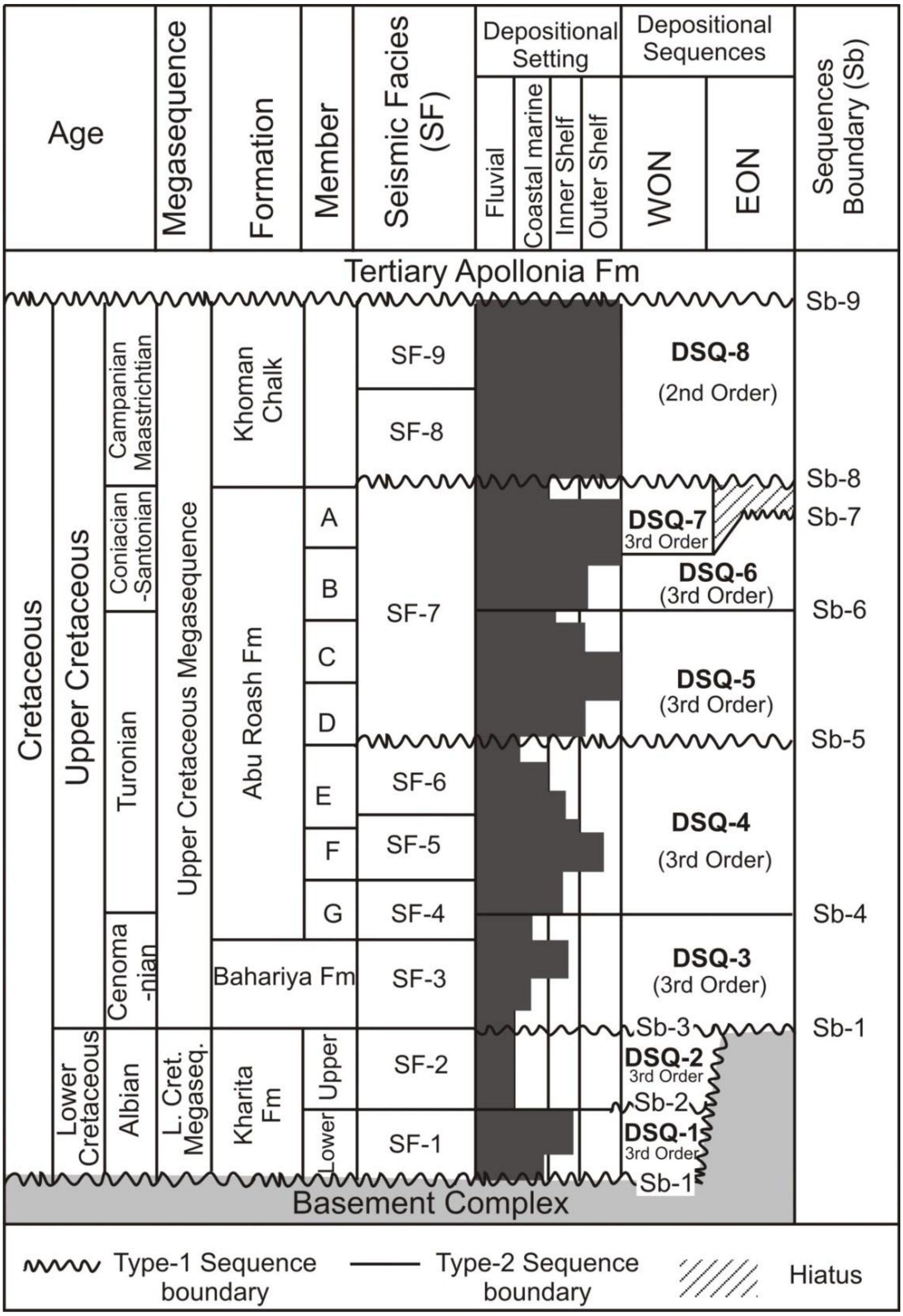
4.4.1. Third-order Depositional Sequences:

4.4.1.1. Depositional Sequence-1 (DSQ-1)

DSQ-1 is only recorded in the WON of the Beni Suef Basin, representing the sediments of seismic facies SF-1, belonging to the Albian Lower Kharita Formation Member. DSQ-1 is bounded by two unconformity surfaces; the lower is Sb-1 (nonconformity surface) discussed before (See 5.1 and Figs. 4 and 9). The upper sequence boundary (Sb-2) is easily detected from both the seismic profile (Fig. 10A) and well data. SeismicallySb-2 is defined due to the presence of onlapping and downlapping terminations (Fig. 9A). On the wireline logs, Sb-2 is proved due to the abrupt decrease in gamma ray and sonic log values coupled with an abrupt increase in the density log values (Fig. 9B), characterizing the transformation from the shales of the Lower Kharita Member to the gravelly sandstones of the Upper Kharita Member.

4.4.1.2. Depositional Sequence-2 (DSQ-2)

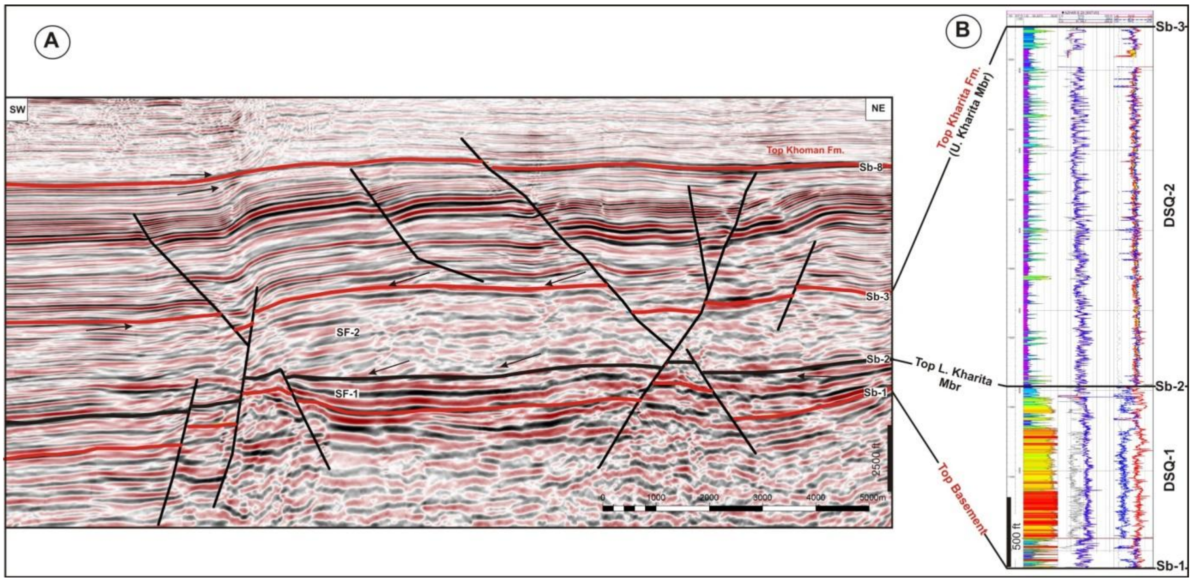
DSQ-2 is only recorded in the WON of the Beni Suef Basin, representing the sediments of SF-2, belonging to the Albian Upper Kharita Formation Member. DSQ-2 is bounded by the two Sb-2 and Sb-3unconformity surfaces, discussed seismically before (See 5.1 and Figs. 4 & 9). On the wireline logs, Sb-3 is further proved due to the abrupt increase in gamma ray and sonic log values, associated with an abrupt decrease in the density log values (Fig. 9B), characterizing the transformation from the fluvial sandstone of the Upper Kharita Member to the shallow marine siltstone and sandstone of the Cenomanian Bahariya Formation.



(Fig. 8): The depositional setting and correlation between the encountered Cretaceous seismic facies, depositional sequences and their boundaries on the both sides of the Beni Suef Basin.

4.4.1.3. Depositional Sequence-3 (DSQ-3)

DSQ-3 is recorded all-over the study area, encompassing the sediments of Bahariya Formation and the lowest part of Abu Roash "G" Member. It comprises both SF-3 and the lowest part of SF-4 of Early-Middle Cenomanian age (Fig. 10A). DSQ-3 is bounded downward by the Sb-3 (unconformity surface) in the WON (Figs. 4 and 9A) and Sb-1 (nonconformity surface) in the EON discussed before (Fig. 4B). The upper sequence boundary (Sb-4) is interpreted on the basis of the well logging data. It is delineated when an abrupt increase in gamma ray and sonic values, coupled with an abrupt decrease in density log values is noticed (Fig. 10A), proving the passage from the almost pure limestone bed in the lower part of Abu Roash Formation "G" Member to the mixed clastics/carbonates succession of the rest of the overlying Abu Roash "G" Member.



(**Fig. 9):** The integration between the seismic (A) and well (B) datasets showing the subdivision of the Lower Cretaceous megasequence into its depositional sequences (DSQ-1 & DSQ-2). Notice the seismic terminations (Black arrows) and the DSQ-4 and its upper boundary Sb-4.

4.4.1.4. Depositional Sequence-4 (DSQ-4)

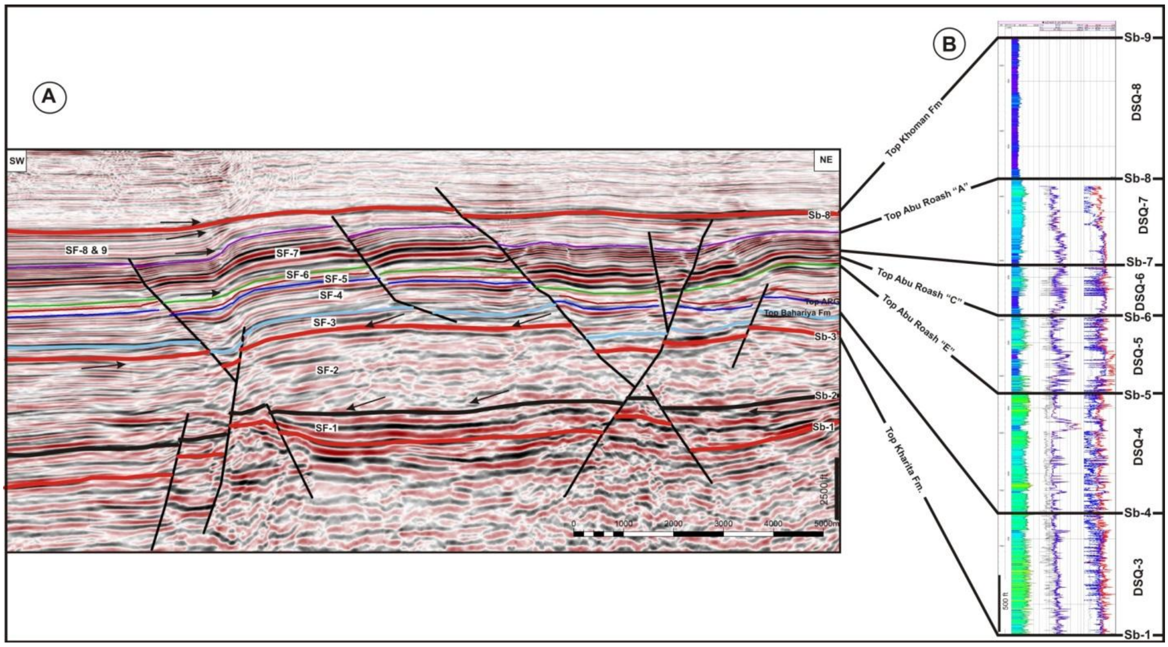
DSQ-4is recorded all-over the study area. This sequence includes the sediments of the remaining part of Abu Roash “G” Member, “F” Member, “E” Member, and the basal parts of "D" Member, representing the remaining part of SF-4, SF-5 and SF-6 of Late Cenomanian-Middle Turonian age (Fig. 10A). DSQ-4 is bounded by two surfaces, the lower is Sb-4 discussed before. The upper sequence boundary (Sb-5) is interpreted on the basis of the geometrical relationship with the overlying basal reflectors of SF-7, displaying onlapping termination over Sb-5(Fig. 7), proving its type-1 sequence boundary characters. Moreover, Sb-5 is further proved due to the well logging data when an abrupt decrease in gamma ray and sonic values, coupled with a sudden increase in density log values is recorded, proving the passage from the mixed clastics/carbonates succession (Abu Roash “E” Member) to the overlying almost pure limestone succession (Abu Roash “D” Member), (Figs. 10B and 11B).

4.4.1.5. Depositional Sequence-5 (DSQ-5)

DSQ-5 is recorded all-over the study area. This sequence includes the sediments of the remaining part of Abu Roash “D” Member, and “C” Member, representing the lower half of SF-7 of Middle-Late Turonian age (Fig. 10A). DSQ-5 is bounded by two surfaces, the lower is Sb-5 discussed before. The upper sequence boundary (Sb-6) is interpreted on the basis of the well logging data when a marked decrease in gamma ray and sonic values, coupled with an abrupt increase in density log values is encountered, proving the passage from the mixed clastics/carbonates succession of the Abu Roash “C” Member to the almost pure limestone succession of the overlying Abu Roash “B” Member (Fig. 10B).

4.4.1.6. Depositional Sequence-6 (DSQ-6)

DSQ-6 is recorded all-over the study area, however it not fully represented in the EON of Beni Suef basin due to post-depositional removal (Fig. 11B).This sequence represents the sediments of Abu Roash “B” Member as a part of the upper part of SF-7 of Coniacian-Santonian age (Fig. 10A). DSQ-6 is bounded by two surfaces, the lower is Sb-6 discussed before. The upper sequence boundary (Sb-7) displays different attitudes in the study basin (Fig. 8). In WON sector, Sb-7 is interpreted on the basis of the well logging data when an abrupt decrease in gamma ray and sonic values, coupled with an abrupt increase in density log values are recorded, proving the passage from the mixed clastics/carbonates succession of the Abu Roash “B” Member and the Lower part of the Abu Roash “A” Member to the pure limestone succession of the overlying rest part of the Abu Roash “A” Member (Fig. 10B).



(Fig. 10): The integration between the seismic (A) and well (B) datasets showing the subdivision of the Upper Cretaceous megasequence into its depositional sequences (DSQ-3 to DSQ-8) in the WON.

In EON, on the other hand, Sb-7 displays truncating reflectors with the underlying reflectors of DSQ-6 (Fig. 5), proving unconformable relations with the overlying sequences due to a stratigraphic hiatus. The Sb-7 is interpreted on the basis of the well logging data when an abrupt decrease in gamma ray and sonic values, coupled with an abrupt increase in density log values are recorded, proving the passage from the mixed clastics/carbonates succession of the Abu Roash “B” and “A” members to the pure limestone and chalky limestone succession of the overlying Khoman Formation (Fig. 10B).

4.4.1.7. Depositional Sequence-7 (DSQ-7)

DSQ-7 is only recorded at the WON sector of Beni Suef basin. This sequence represents the sediments of Abu Roash “A” Member as the top part of SF-7 of Coniacian-Santonian age (Fig. 11A). Wherever present in the WON sector, DSQ-7 is underlain by Sb-7 discussed above, whereas it is topped by Sb-8 displaying marked truncation with the overlying DSQ-8 of Khoman Chalk (11A). Sb-8 represents a general unconformity surface with low-angle geometric relation over the study area and many parts of Egypt ([30]).

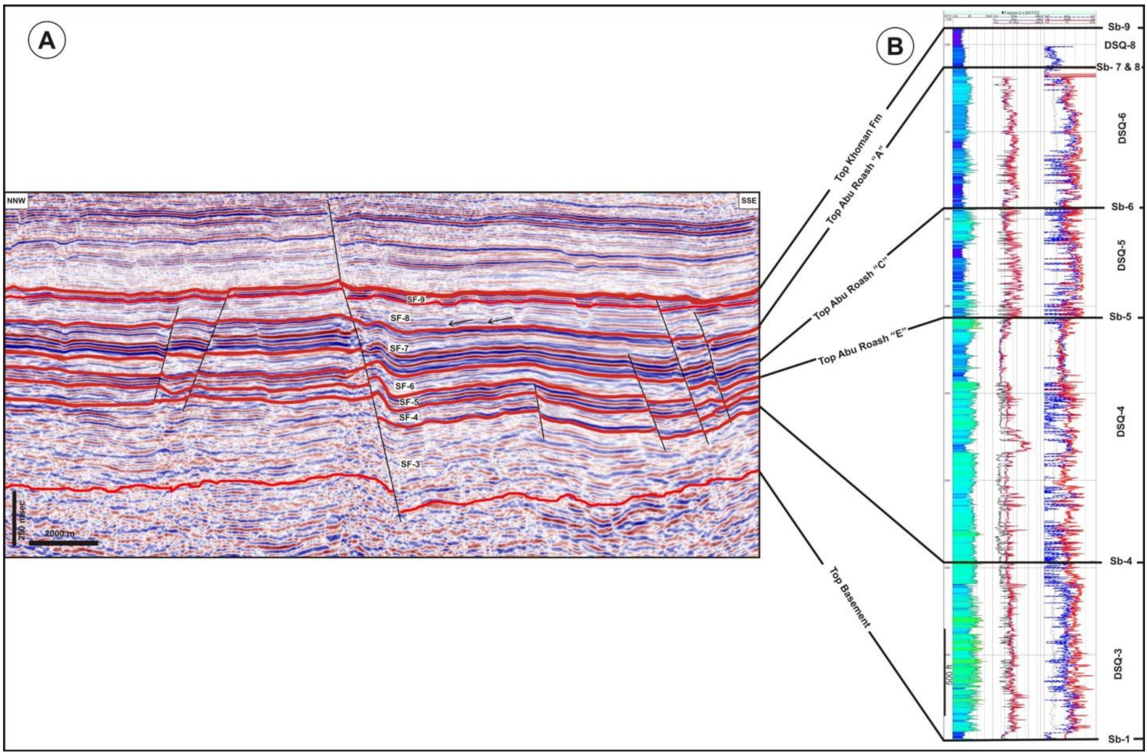
4.4.2. Second-order Depositional Sequences:

4.4.2.1. Depositional Sequence-8 (DSQ-8)

DSQ-8 is a 2nd order depositional sequence that deposited all-over the study area. This sequence represents the sediments in Khoman Formation and contains the SF-8 and SF-9 of Campanian -Maastrichtian age (Figs. 10A and 11A). DSQ-8 is bounded by two surfaces, the lower is Sb-8 discussed before. The upper sequence boundary (Sb-9) representing the K/T boundary as it has been discussed before (see 5.1 and Figs. 10B and 11B).

V. Discussion and Conclusions

The Cretaceous succession in the Beni Suef Basin is subdivided into two main megasequences; Lower Cretaceous Megasequence and Upper Cretaceous Megasequence. Each one shows clear variations in the seismic facies characters and the well-logging data. Accordingly, this succession is subdivided into nine seismic facies; two in the Lower Cretaceous Megasequence and seven in the Upper Cretaceous Megasequence. The integration between the seismic and well-logging datasets enabled the subdivision of the Cretaceous sediments into eight depositional sequences with definite boundaries. The seismic facies analyses and the depositional sequences investigation enabled recognition of the regional depositional framework of the Cretaceous sediments in the studied basin. Moreover, the external form of depositional megasequences commonly expresses the general external geometry of that sediment-body ([28]). For the Lower Cretaceous Megasequence; it displays a general external form of sheet-like to wedge-shaped geometry (Fig. 4A), typically characterizing wide fluvial-to-marine depositional settings. In such setting, the sediments tend to generate seismic facies having parallel reflection configurations that graded basin-ward ([1], [2], [3] and [4]). Moreover, within this depositional setting, the reflectors are concordant at the base (time of the non-conformity surface, Sb-1) and onlapped by coastal facies (time of Sb-3) at the top (Fig. 4A).



(**Fig. 11):** The integration between the seismic (A) and well (B) datasets showing the subdivision of the Upper Cretaceous megasequence into its depositional sequences (DSQ-3 to DSQ-8) in EON.

By the Early Albian, the Lower Cretaceous Megasequence started deposition by the sediments of the Lower Member of Kharita Formation; well stacked layers deposited in variable energies (SF-1), reflecting alternative coastal to inner-shelf marine deposition of DSQ-1 (Fig. 9). With the Late Albian, the sediments of the Upper Member, Kharita Formation were deposited within high energy turbulent regime (SF-2), assuming long-lasted fluvial sedimentation of DSQ-2 (Fig. 8).

With the Early Cenomanian, the Upper Cretaceous Megasequence started to build-up its sedimentary sequences. The megasequence displays a general external form of giant sheet geometry (Figs. 4A & B, 6 and 7), typically characterizing the shelf depositional setting ([1], [2], [3]and [4]). In such shelfal settings, sediments facies tend to generate parallel to gently divergent reflection configurations. In the shelf setting, the reflectors are normally concordant toward the top, whereas they vary from concordant to gently onlapping and occasionally downlapping at the base (([1], [2], [3] and [4]) as recorded in Figs (4A and 10A). The deposition started within high energy regimes related to high energy fluvial currents that were later redistributed in coastal marine conditions (DSQ-3). This is followed by a long period of sea-level fluctuations resulted in the development of the overlying successive depositional sequences (DSQ-4 – DSQ-7), deposited within fluctuating low to high energy regimes of coastal-to-deep marine conditions (Fig. 8). The depositional history of the Upper Cretaceous Megasequence in Beni Suef Basin was closed by the deposition of thick units having a uniform low to moderate energy with extensive bed geometry (DSQ-8). This is suggested the deposition in outer marine an open shelf conditions. The deposition of both megasequences was intermittently overprinted by several episodes of the local and regional tectonic events influenced the area.

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