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Resolving Stratigraphic Uncertainties in East Ghazalat Area, Sharib-Sheiba High, North Western Desert, Egypt; New Insights into the Paleozoic, Jurassic and Cretaceous Rocks

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DIFFERENTIATING between Paleozoic and Jurassic rocks in the North Western Desert of Egypt is challenging and often results in misinterpretation of one as the other. Such discrepancies arise from several factors, including limited knowledge of the Paleozoic geology in Egypt, challenges and uncertainties in biostratigraphic age determination and similarities in facies between some Jurassic and Paleozoic units. This research contributes to resolve key stratigraphic uncertainties in the East Ghazalat area, located in Sharib-Sheiba High in the North Western Desert. It integrates regional geological insights, E-logs correlation with nearby key wells, facies analysis, palynological examination, and seismic interpretation. The study re-evaluates the age of the sedimentary section overlying the basement in the Sahab-1X well (6,440-8,180 ft.), which was previously assigned as a Jurassic age based on biostratigraphic data. The re-assessment suggests that this interval is more consistent with the Paleozoic rather than the Jurassic. Additional palynological analysis identified Middle to Late Cambrian acritarchs (palynological zone WD2) corresponding to the Shifah Formation in the North Western Desert, which led to the reclassification of much of the Jurassic units. Furthermore, the study proposes a revised stratigraphic subdivision for key Cretaceous units (Kharita, Lower Bahariya, Upper Bahariya, and A/R "G"), ensuring better consistency with age assignments from regional studies, aligning with the stratigraphic schemes of adjacent fields, and unifying local nomenclature. It also addresses uncertainties regarding the presence of the Alam El Bueib and Khoman formations due to the impact of major unconformities, extending their geographic distribution in previously unrecognized areas. The findings enhance the understanding of the study area's geological evolution and tectono-stratigraphic framework, and aids in refining play concepts across the region. This work provides a solid foundation for future exploration, development and research, both within the area or in similar geological setting.

Keywords: North Western Desert, Egypt; Sharib-Sheiba High, Paleo-Highs; East Ghazalt; Tectono-stratigraphic evolution; Paleozoic-Jurassic differentiation; Cretaceous stratigraphy subdivision; Unconformities.

1. Introduction

East Ghazalat is an onshore area located in Ras Qattara Depression in the central part of the North Western Desert of Egypt, about 200 km southwest of Alexandria city. The study area covers around 450 Km^2 and lies between Latitudes 30° 06′ 45″ to 30° 02′ 45″ N, and Longitudes 28° 06′ 35″ to 27° 59′ 44″ E (Fig. 1). It is situated in the vicinity of several oil and gas fields and includes Safwa-Sabbar and NEAG-5 oil fields that producing from Lower Bahariya reservoir. These two fields together represent about 11 % of the study area, while the remainder is mainly exploration acreage (Fig. 1). The central portion of the study area where Safwa-Sabbar and NEAG-5 fields occur, has a favorable geological setting for hydrocarbon accumulation. Both fields are producing from the same trap and share the same reservoir, but under different

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concessions and different operating companies, PETROSAFWA and BAPETCO, respectively. However, Safwa-Sabbar Field accounts for around 80% of the entire trap (Figs. 1 & 5).
The area was previously studied by El Redini et al. (2016, 2017) and Hassan et al. (2018, 2021). However, their work focused mainly on the Safwa-Sabbar Field, whereas the current study covers a broader area of approximately 450 km² (Fig. 1). In addition, the scope and objectives of their work differ from those of the present research. In particular, the earlier studies relied on the previous formations' definitions and stratigraphic subdivisions.

On the other hand, the main objective of the current study is to address and resolve key stratigraphic uncertainties in the stratigraphic column of the study area, re-defines certain stratigraphic units, and offers new insights into the stratigraphic framework of the area, thereby adding value to the previous work and supports future activities in the region.

First, it re-evaluates the age of the sedimentary section overlying the Pre-Cambrian basement, which was previously defined as Jurassic, and re-defines it as Paleozoic instead; therefore, refined the subdivision of almost the entire Jurassic units. The research also reviews the two stratigraphic schemes used by various operators to subdivide Kharita, Lower Bahariya, Upper Bahariya, and Abu Roash "G" (A/R "G") rock units. The analysis recommends adopting the second scheme, which is currently not applied, as it aligns better with the regional age assignments, improves differentiation between Upper Bahariya, Lower Bahariya and Kharita units, and would benefit future development activities in the area. The study also addresses uncertainties regarding the presence of Alam El Bueib and Khoman formations, that exist mainly from the severe effect of the major unconformities on their thicknesses and characteristic markers. New evidence is presented about their extended spatial distribution. Besides, the study estimates the thickness of the missing sections in the area by correlation with nearby more complete wells. It also delineates the distribution of the different units beneath the major unconformities by generating sub-crop maps for these unconformities and a chrono-stratigraphic chart for the wells.
The findings underscore the value of integrated approaches in resolving such stratigraphic uncertainties and emphasize the importance of regionally calibrated stratigraphic studies, contributing to a more comprehensive understanding of the area's geological history.

2. Data Set

This research is based on a variety of datasets (Fig. 2), which include:

Well Data: This study incorporates data from four wells, including biostratigraphic data, mud logs, E-logs, final well reports, and checkshots. Three wells among the four wells have bio-stratigraphic reports, they are Sahab-1X, Sabbar-1X and Nakhil-1X. Two separate previous biostratigraphic analysis were performed in Nakhil-1X and Sahab-1X wells. The first (foraminifera and palynology), conducted directly after drilling, almost for the entire penetrated section, whereas the second (foraminifera only), made later and focused on small selected intervals.
Seismic Data: A total of twenty (20) 2D seismic lines were used in this study; they were extracted from the 3D seismic survey acquired in 2008, which covers the entire study area (about 450 Km^2).

3. Methodology and Workflow

This study adopts a systematic, multi-step approach (Fig. 3) as outlined below:

3.1 Data Collection and Database

Seismic and well data were gathered, reviewed and integrated into a well-established database.

3.2 Review of Previous Work

Regional and local previous related work were reviewed to ensure consistent integration into the study area's geological framework.

3.3 Bio-Stratigraphic Data Review

The two existing biostratigraphic studies were critically reviewed by comparing their bio-charts with the corresponding reports manuscript for the same well, then cross-checking with other wells to identify bio-zones, their ages, and the corresponding stratigraphic units. The results were integrated with E-logs to compare bio-stratigraphic and litho-stratigraphic formations definition, ensuring that the same bio-zones correspond to the same unit laterally from one well to another. Where the two bio-data conflicts, the interpretation most consistent with the regional geological context, conceptually accepted, and supported by other data was adopted, and the outcomes were cross-referenced with other wells.

3.4 Regional Context and Operators Discussions

Discussions with nearby operators focused on their stratigraphic subdivision schemes and the age of the basement-overlying interval, indicating a Paleozoic age for these units in their areas. This interpretation is supported by data from nearby wells reported in published regional studies.

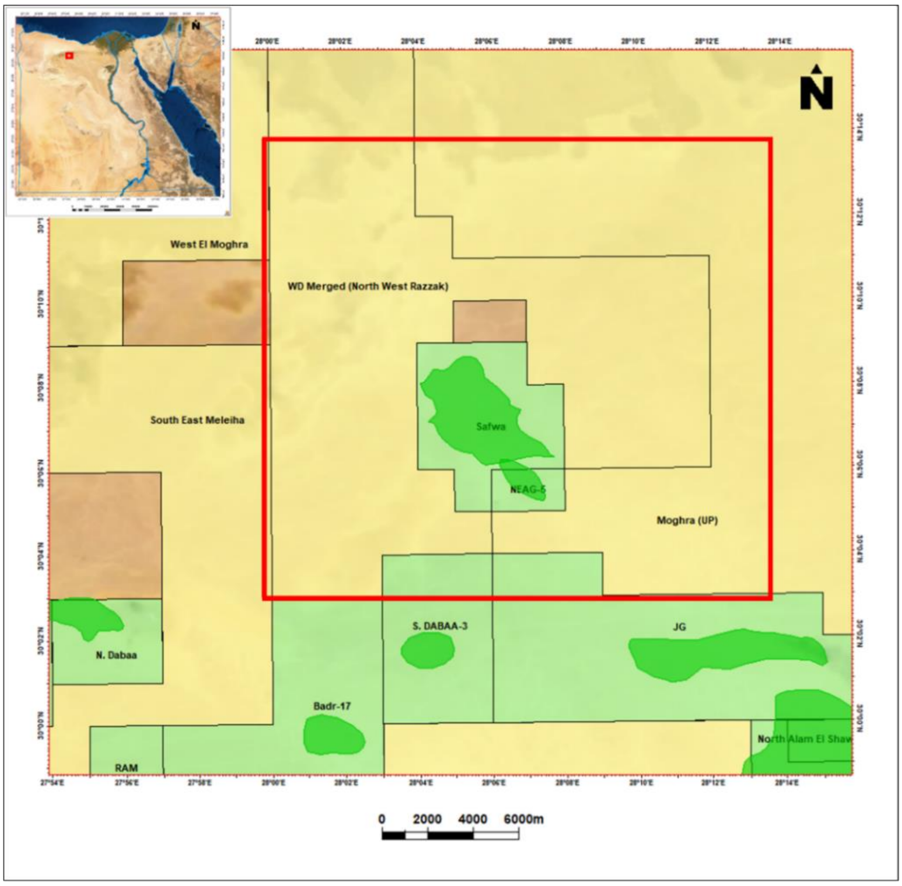

Fig. 1. Location map for the study area (modified after Google Maps). The red square indicates the study area; green shading represents producing fields; yellow color represents exploration areas; the rest is open area.

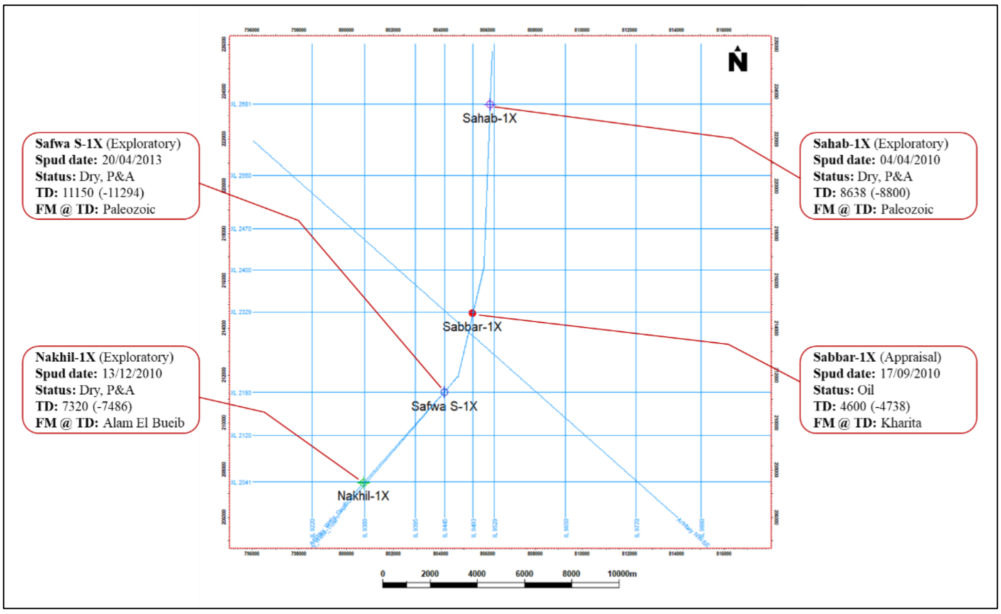

Fig. 2. Base map showing the wells and seismic data used in the present study.

3.5 Palynology Analysis

Palynological analysis was carried out for seven selected samples from Sahab-1X well to confirm this interval age.

3.6 Formations Definition and Correlation

Final formation tops were established by integrating reliable bio-data, mud logs data, final geological reports, and E-logs correlation using Petrel software.

3.7 Seismic Interpretation and Mapping

Seismic interpretation, structural maps, thickness maps, and sub-crop maps were constructed for key geological levels using Petrel software. All results were integrated to detect missing units, estimate their thicknesses and construct a chronostratigraphic chart among wells and burial history.

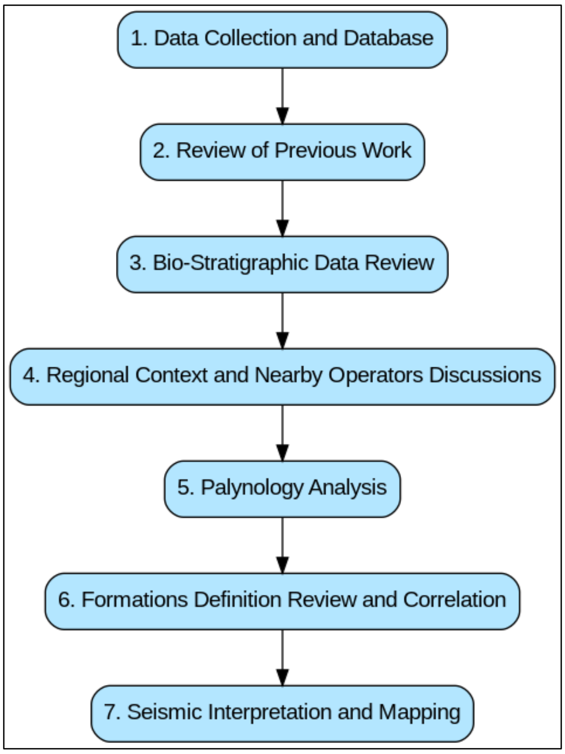

Fig. 3. Flow chart for the methodology and workflow used in this study.

4. Geological Setting of the Study Area

4.1 Structure Setting of the Study Area

In the subsurface and structurally, the study area lies in the southern part of Sharib-Sheiba High (also referred as Qattara High), (Fig. 4). Sharib-Sheiba is an east-west trending paleo-high, characterized by faulted blocks with the highest basement relief, the thinnest and most interrupted sedimentary sequence relative to the surrounding region. It separates Abu Gharadig Basin to the south and Alamein Basin to the north (Fig. 4). The southern margin of Sharib-Sheiba High is controlled by an east-west oriented fault system with large and variable throws, down throwing to the south. In places, these major faults extend to the surface due to reactivation during the Tertiary. However, the displacement of the Tertiary deposits along these faults is relatively minor, indicating limited reactivation magnitude. The northern boundary of the High is controlled by regional north-dipping step faults with smaller throws, downthrowing into Alamein Basin (after H.B.S.I, 2004).

The study area can be subdivided into three geological sub-provinces from north to south: Platform or High area, transitional sliver block and basinal area (Figs. 5 & 6), which are represented by Sahab-X, Safwa-S-1X and Nakail-1X wells, respectively.

These provinces are separated by a major fault system composed of ENE, E-W, NW and nearly N-S fault segments (labeled F2 in Figs. 5 & 6). The maximum throw along this fault exceeds 2000 feet. Beyond this major fault (F2), the dominant fault trends are NW-SE to WNW-ESE, with subordinate trends including E-W, ENE to NE, and NNW (Fig. 5). The major faults in the study area are basement-controlled, and the intensity of the structural deformation increases with depth toward the basement, reflecting superimposed structures formed during multiple tectonic phases. Another distinct fault style is observed in the Apollonia Formation only which has random orientations and could be interpreted as non-tectonic minor gravitational faults either during or directly after the deposition of the Apollonia Formation (Fig. 6).

4.2 Stratigraphy of the Study Area

The stratigraphic succession of the study area starts with the Cambrian Shifah Formation, which overlies the Pre-Cambrian basement, and extends upward to the Early Miocene Moghra Formation exposed on the surface (Fig. 8). The study area has been severely affected by at least five major unconformities of different magnitude, resulting in the absence of several Paleozoic and Cretaceous units either due to erosion or non-deposition. The amount of erosion, thus, the thickness of missing units generally increases toward the northern structural High and decreases toward the southern Basinal area. The average sedimentary thickness ranges from about 9,500 ft., in the High area to around 14,000 ft., in the southern Basinal area (Figs. 5 & 6).

To better recognize the effect of the major unconformities, two sub-crop maps were constructed for top Dahab and top Abu Roash unconformities (Figs. 9 & 10). These maps show the distribution of the preserved stratigraphic units across the study area. Moreover, using the available biostratigraphic data and final formation tops, a chrono-stratigraphic chart (Fig. 7) was constructed among the four wells included in this study. The Safwa-South-1X well was correlated using E-Logs then calibrated to align with the age framework of the other wells.

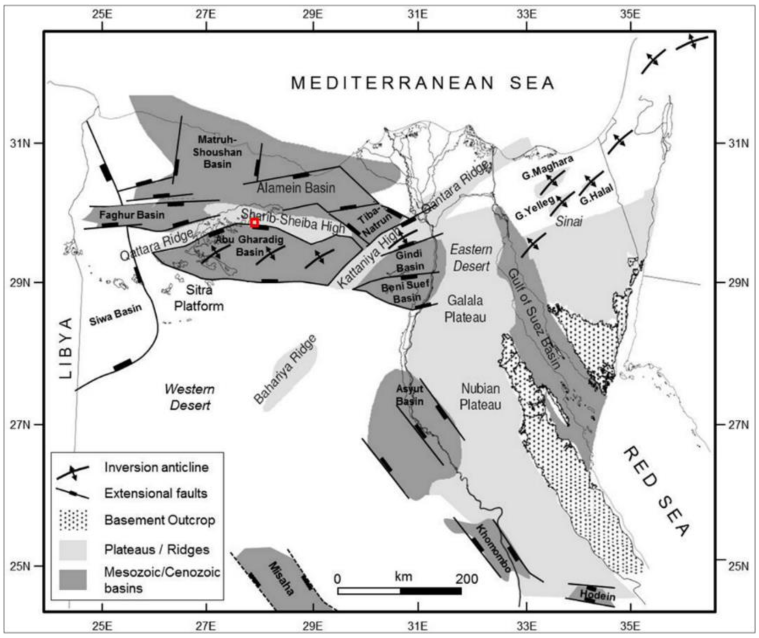

Fig. 4. Location map of the study area (red rectangle) in relation to the Western Desert subsurface basins (after, Dolson et al., 2001, Bosworth et al., 2008; Moustafa, 2008; Bevan & Moustafa, 2012 as cited in El Gazzar, 2016).

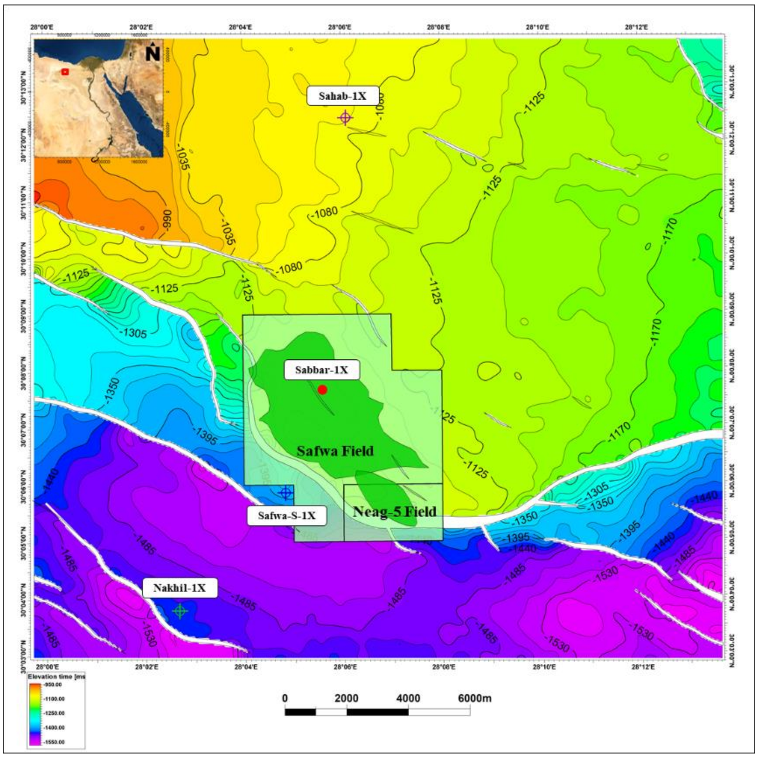

Fig. 5. Top Lower Bahariya two-way time (TWT) structure map showing the location and trap of Safwa-Sabbar and Neag-5 fields.

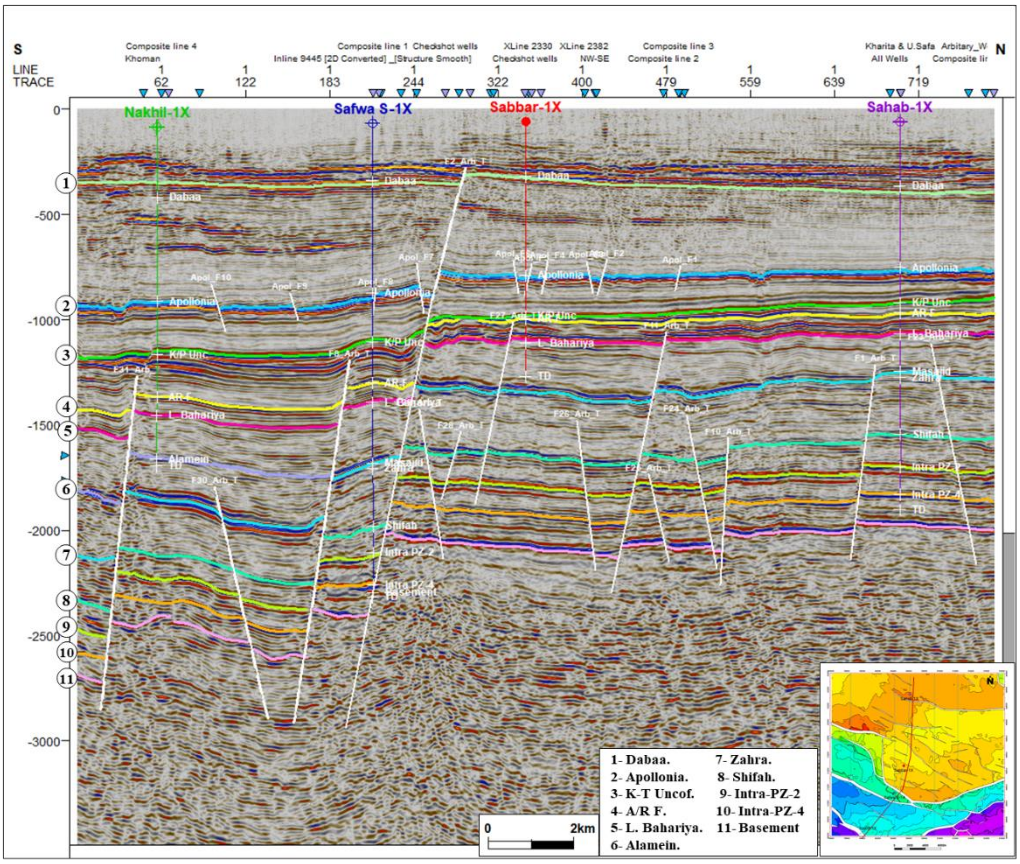

Fig. 6. Interpreted arbitrary TWT seismic line showing the structural configuration and passing through the four wells included in this study. The Index map is top Shifah TWT structure map.

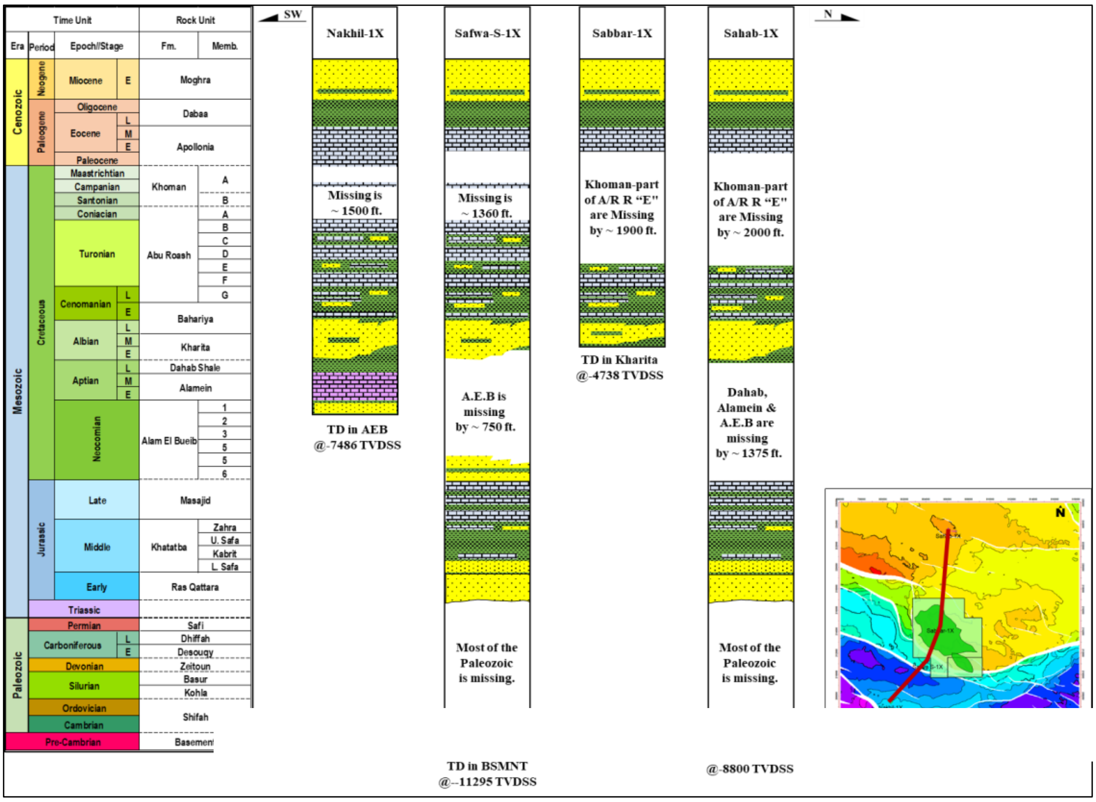

Fig. 7. Chrono-Stratigraphic chart among the four wells in this study, the missing sections is noted on the chart. The Index map is top Masajid TWT structure map.

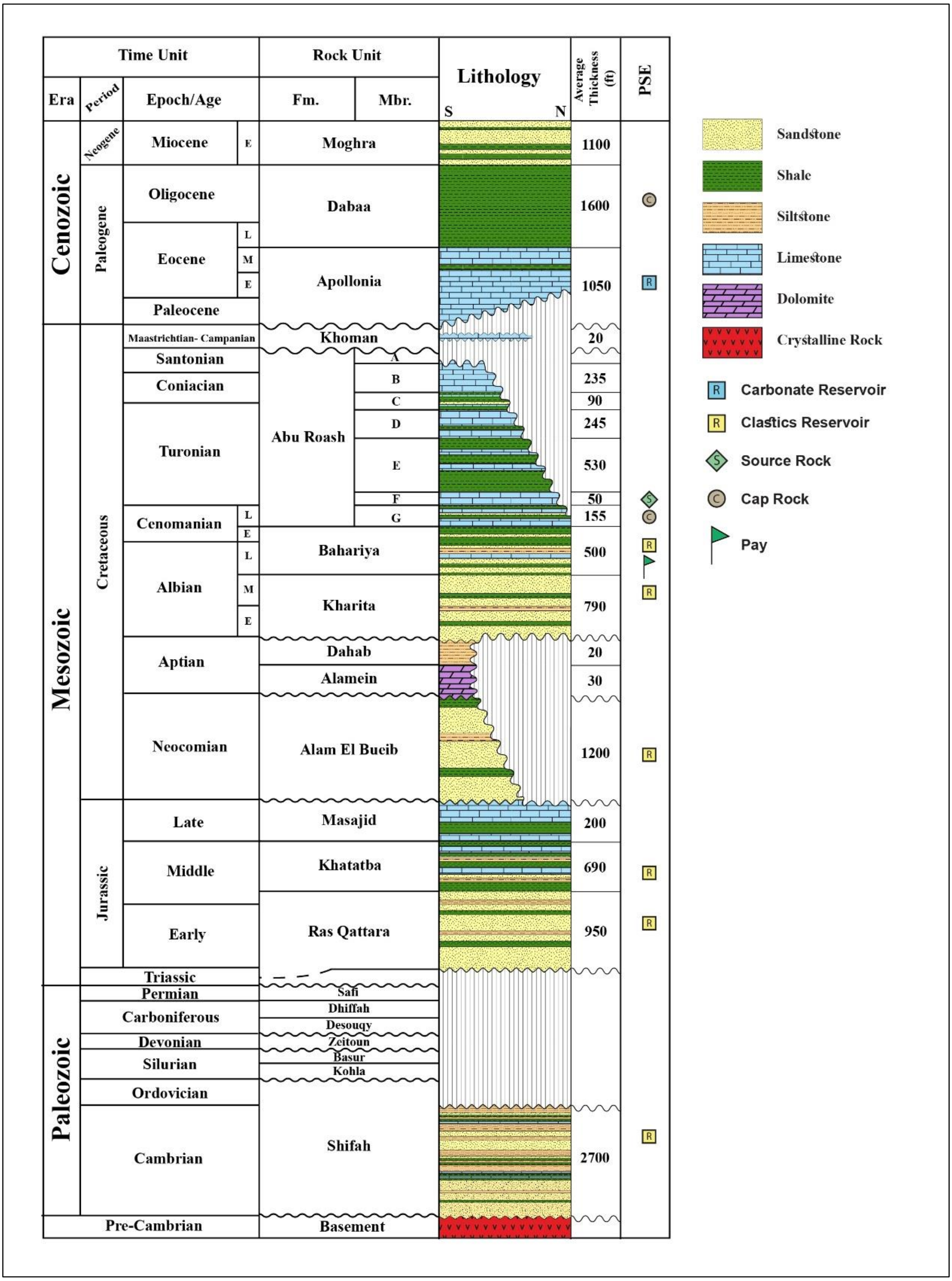

Fig. 8. Generalized stratigraphic column of the study area, showing greater erosion in the northern High area and better preservation in the southern Basinal area.

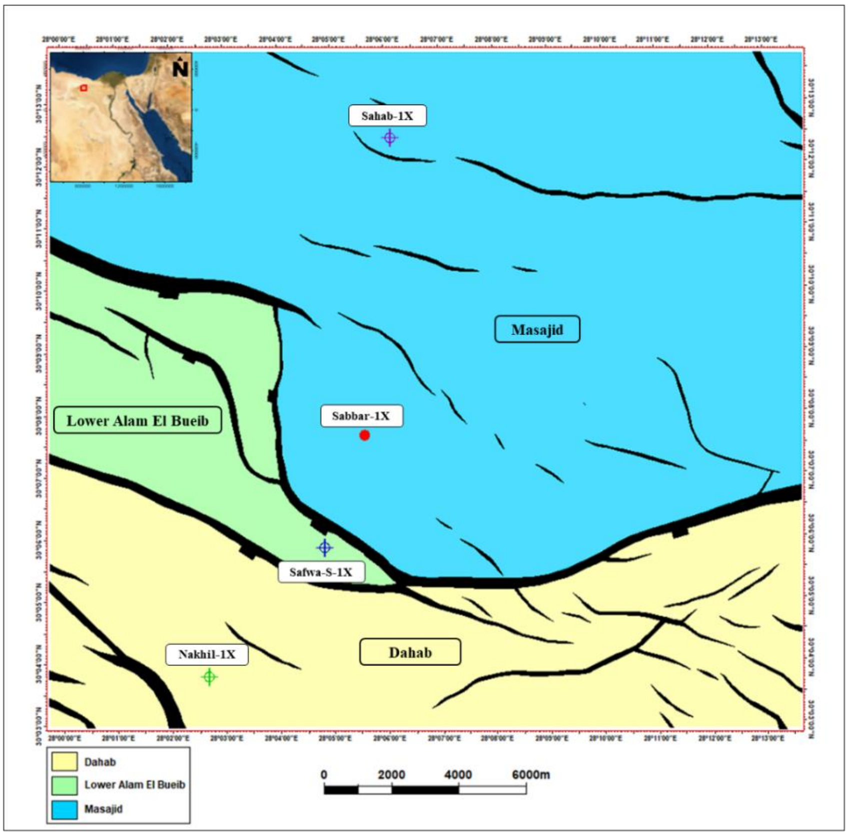

Fig. 9. Sub-crop map for top Dahab unconformity, showing the distribution of different units beneath it. Masajid fault polygon is overlain.

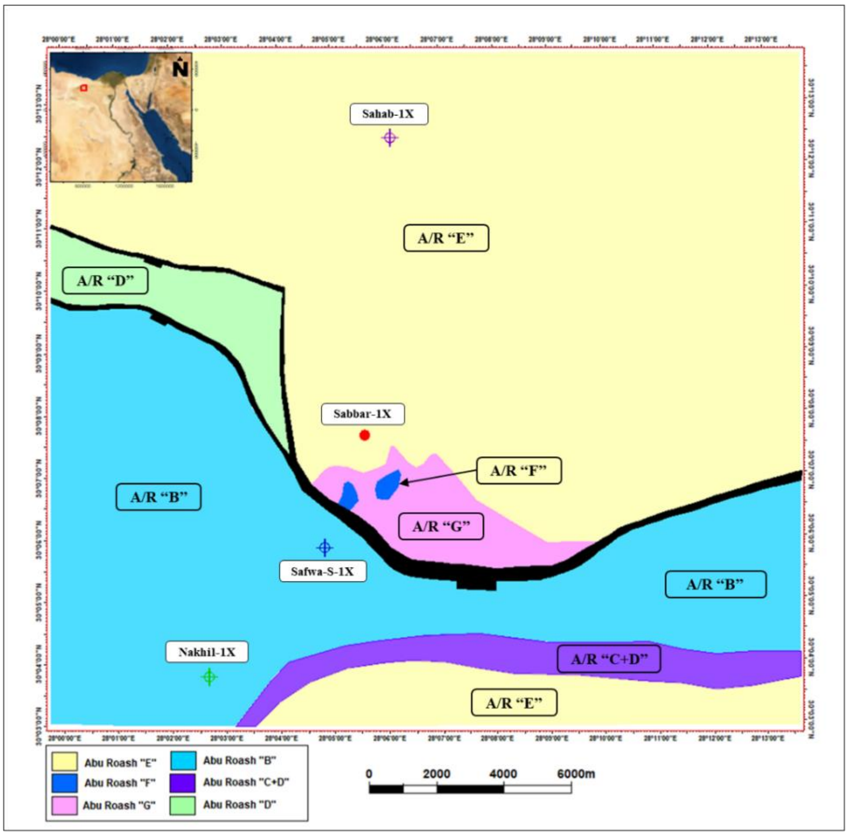

Fig. 10. Sub-crop map for top Abu Roash unconformity, showing the effect of the differential erosion on the study area, A/R "F" major faults polygon is overlain.

5. Results and Discussion

5.1 The Paleozoic–Jurassic Age Dilemma

The Paleozoic geology of Egypt, particularly the sub-Hercynian, is poorly understood due to the scarce Paleozoic outcrops and insufficient subsurface data (Moustafa, 2008; Dolson et al., 2014; Moustafa, 2020). In the subsurface of the North Western Desert, it is common to face challenges and uncertainties in the age dating and identification between Jurassic and Paleozoic rocks which are frequently miss-assigned as one another. A notable example is the Qasr Field, where Paleontological data initially indicated a Paleozoic age for the producing reservoir. However, due to uncertainties, radiometric age dating was performed later on core samples, revealing a Jurassic age instead.

Such misinterpretations arise from several factors, including, limitations in bio-stratigraphic data (e.g., caving, reworking, barren samples, and undefined sections) that are more pronounced in the deeper Jurassic and Paleozoic intervals. The bio-stratigrapher experience and the quality of samples preparation are also critical for accurate differentiation. In addition, the similarity in facies between definite Jurassic and Paleozoic units, further complicates the differentiation. Compounding these issues is the limited number of operators exploring the Paleozoic plays in the Western Desert and the shortage of related publications restricts much of the Paleozoic knowledge to the operating companies in such areas.

In the study area, the sedimentary section overlying the Pre-Cambrian basement (Fig. 11) in Sahab-1X (basement not penetrated) was previously assigned as a Jurassic age based on bio-stratigraphic analysis (Fig. 12). This section was interpreted to contain from base to top, the Jurassic Ras Qattara, Wadi El Natrun, Yakout, Lower Safa, Kabrit and Upper Safa units (Figs. 11 & 12). However, the findings of the present study challenge this Jurassic age assignment and interpretation for the following reasons:

1) **Discrepancies in Bio-Stratigraphic Reports** Previous reports (mainly the first run) contain numerous typographical mistakes and inconsistencies, which undermine their reliability to some extent. For instance, In Sahab-1X report, Ras Qattara Formation is dated as Aelanian-Toarcian in the report's conclusion, but it is Hettangian-Toarcian age in the detailed bio-zones description and palynological distribution chart, with no explanation for this discrepancy. Similarly, Yakout and Wadi El Natrun formations are defined as Middle Jurassic in the conclusion part, based on the acme of *Dichadogonyaulax sellwoodi*, while, in the detailed analysis, only Yakout's depth is documented without any bio-zones description. Besides, in the palynological charts, only Yakout is stated with its related bio-zones and Wadi El Natrun is not labeled, despite the presence of Palynomorphs description at its depth.

2) **Facies Similarity to Paleozoic Units** this interval exhibits facies more similar to the Paleozoic succession in the North Western Desert, characterized by over-scale gamma ray and high kaolinite content (Fig. 11, Table 1).
3) **Unusual Characteristics of Upper Safa Unit** The previously described Upper Safa interval exhibits an unusual thick net sand reservoir (average 840 ft.) (Fig. 11). This is inconsistent with the normal characteristics of Upper Safa in the North Western Desert.
4) **Insights from Regional Published Studies** Regional evidences further dispute the Jurassic assignment for this interval. The regional Paleozoic maps of (Dahi & Shahin, 1992) (Fig. 13), and (Hantar, 1990) show thickness of about 3000 ft. in the study area. Moreover, nearby wells, like Sharib-1 (20 km east of Sahab-1X) and Sheiba-1 (55 km east of Sahab-1X) are reported to bottom in Paleozoic equivalent rocks (Hantar, 1990; EGPC, 1992).
5) **Conflicts with Wadi El Natrun Regional Distribution**
The interval assigned to the Jurassic Wadi El Natrun in Sahab-1X has an average thickness of only 55 ft., and contains two dolomite streaks with a total thickness 16 ft. (Fig. 11). This contrasts sharply with the well-documented Wadi El Natrun carbonate facies, which attains 650 ft. in average in its basinal areas (EGPC, 1992). Furthermore, it conflicts with the regional distribution map of Hantar (1990), showing the absence of Wadi El Natrun in the study area (Fig. 14).
6) **Correlation with Key Nearby Wells**
The correlation with additional wells (not included in this paper) drilled by different operators such as JG-16 (23 km southeast of Sahab-1X), Qasr-55X

with robust age dating control, and Neag 5-6 (7 km southeast of Sahab-1X), also indicates a Paleozoic age for this interval.

Although these findings strongly challenge the previously assigned Jurassic age, however, it was based on biostratigraphic data. Therefore, reclassifying this interval as Paleozoic requires further biostratigraphic confirmation. For this purpose, a palynological analysis was conducted on seven selected samples from Sahab-1X well at depths, 6440', 6460', 6680', 7420', 7580', 8100' and 8180', (Figs. 11 & 15). The results indicate a Paleozoic age, specifically Middle to Late Cambrian, as evidenced by the presence of palynological zone (**WD2**), which corresponds to Shifah Formation in the North Western Desert. The recovered palynomorph assemblages include association of taxa of caved Jurassic miospores and dinocysts, along with Middle to Late Cambrian acritarchs.

A detailed description is provided in (Fig. 15).Based on the above results, a revised stratigraphic subdivision and age assignment have been established, replacing the previously defined Jurassic units with newly subdivided Paleozoic and Jurassic units. The units previously identified as Jurassic, Ras Qattara, Wadi El Natrun, Yakout, Lower Safa and Kabrit are re-assigned to the Paleozoic Shifah Formation. In addition, Upper Safa is re-defined as Ras Qattara and Zahra as Khataba Formation.

The Shifah Formation is further subdivided into five units, locally designated from top to base as Intra Paleozoic-1 through Intra Paleozoic-5 (Fig. 11 & Table 1). These markers show minimal lateral thickness variation (Fig. 6), and correlatable from one well to another. The description and thickness of these units are provided in Table 1.

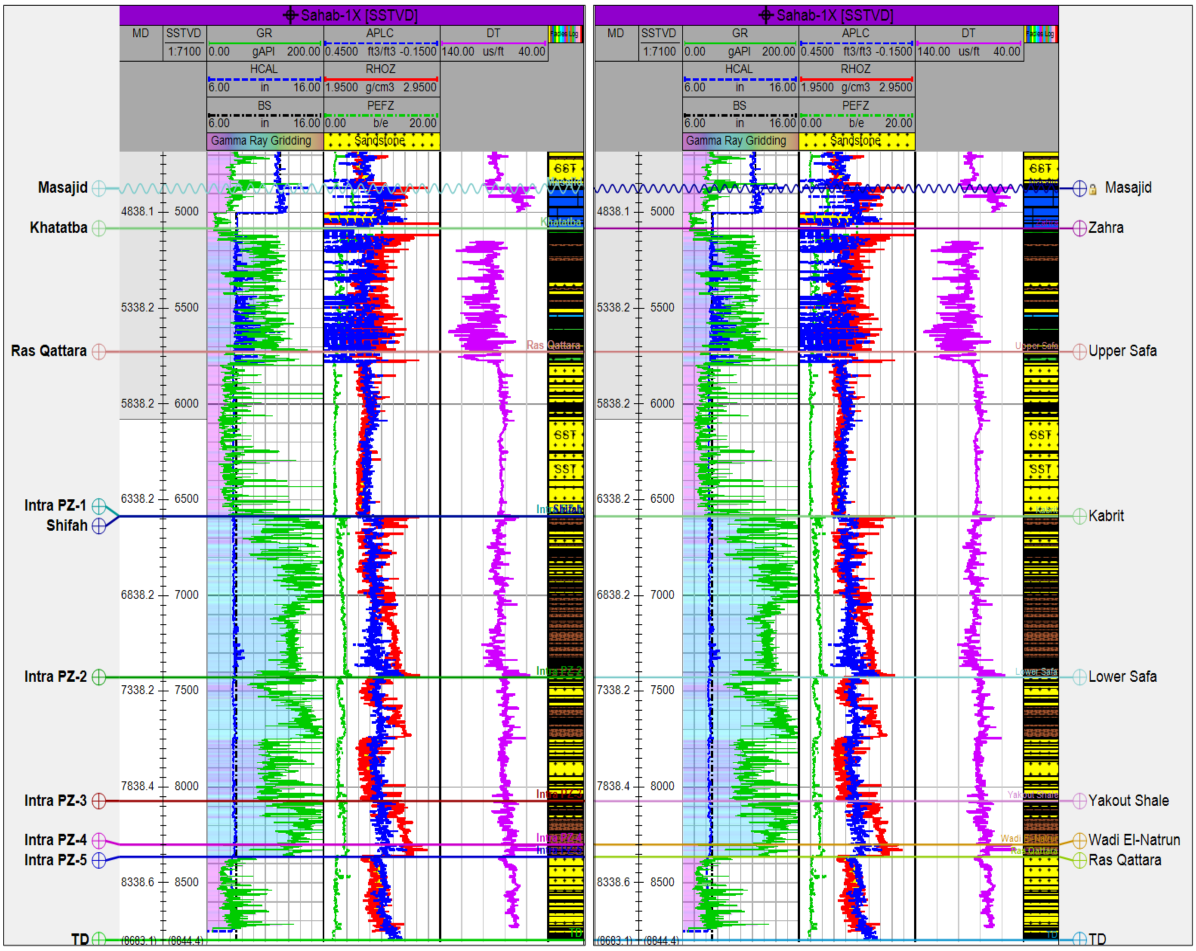

Fig. 11. Comparison between the old (right) and the new (left) definitions of the Paleozoic and Jurassic units in the study area.

Table 1. Comparison of the old and the new interpretations of the Paleozoic and Jurassic units in the study area.

Old Definition		New Definition			Lithology	Average Thickness ft. (TVDT)
Age	Stratigraphic Units	Age	Stratigraphic Units			
Jurassic	Zahra	Jurassic	Khatatba		sandstone, siltstone, shale & traces of limestone	690
	Upper Safa		Ras Qattara		sandstone with shale and siltstone streaks	950
	Kabrit	Paleozoic (Cambrian)	Shifah	Intra PZ-1	siltstone, sandstone, shale and limestone streaks	830
	Lower Safa			Intra PZ-2	sandstone, siltstone, shale and limestone streaks	670
	Yakout			Intra PZ-3	reddish siltstone, sandstone and shale streaks	230
	Wadi El Natrun			Intra PZ-4	siltstone, dolomite and shale streaks	60
	Ras Qattara			Intra PZ-5	kaolinitic sandstone, siltstone and shale streaks	900
Basemnet Rocks						

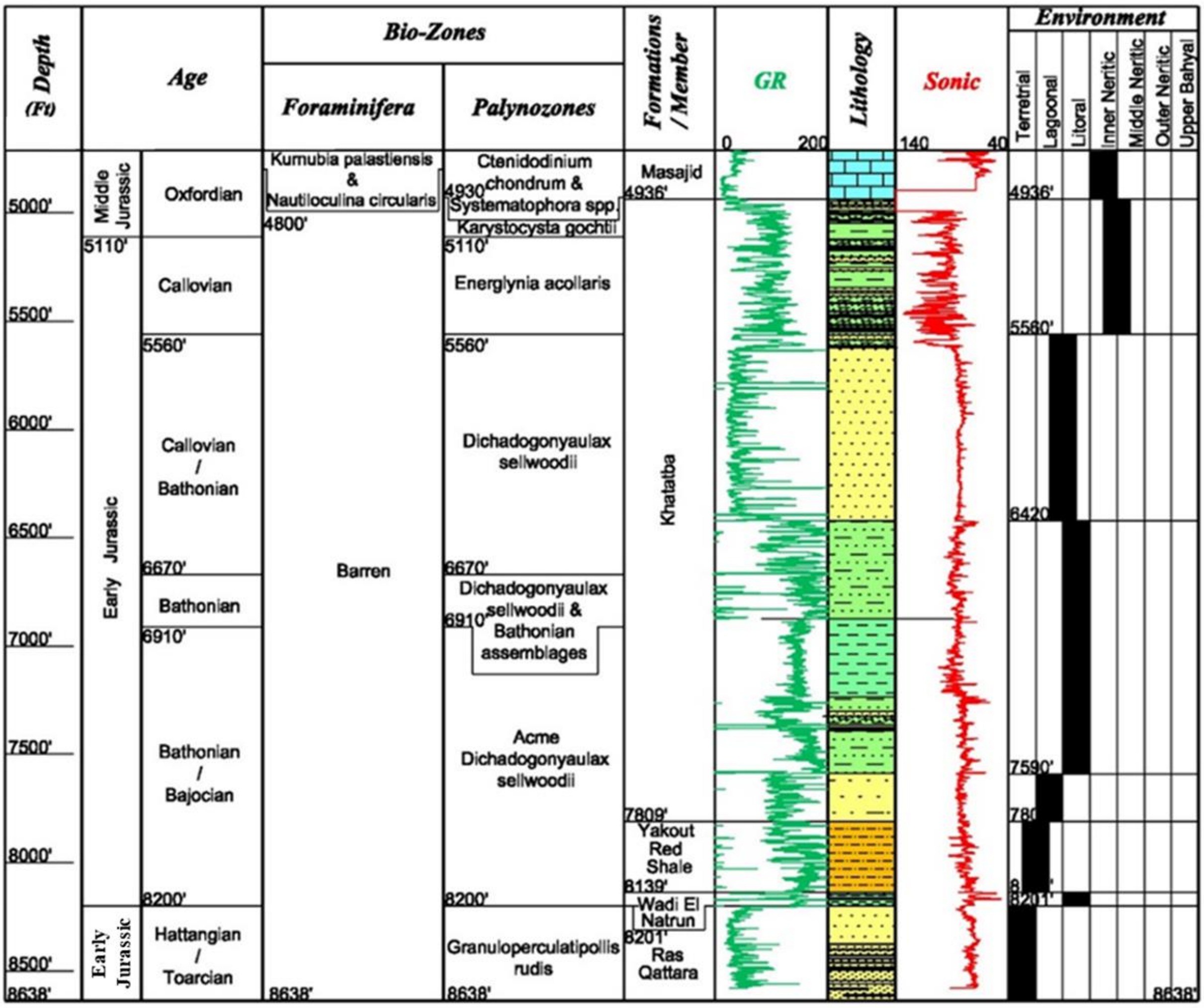

Fig. 12. Summary chart of Sahab-1X well previous biostratigraphic report, showing a Jurassic definition for the section overlying the basement (after Petroguide, 2010).

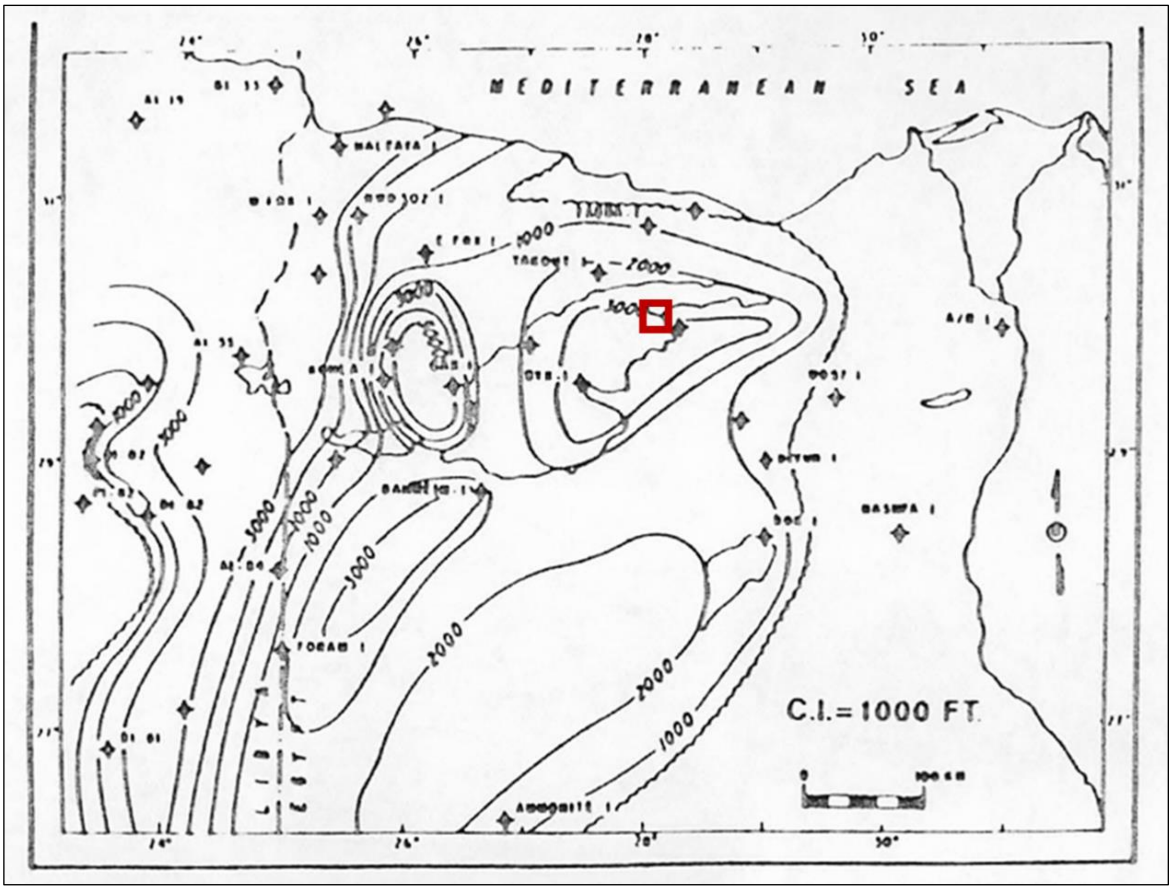

Fig. 13. Regional isopach map for Shifah Formation (Cambrian-Ordovician), showing a thickness of around 3000 ft. in the study area (red square), (after Dahi and Shahin, 1992).

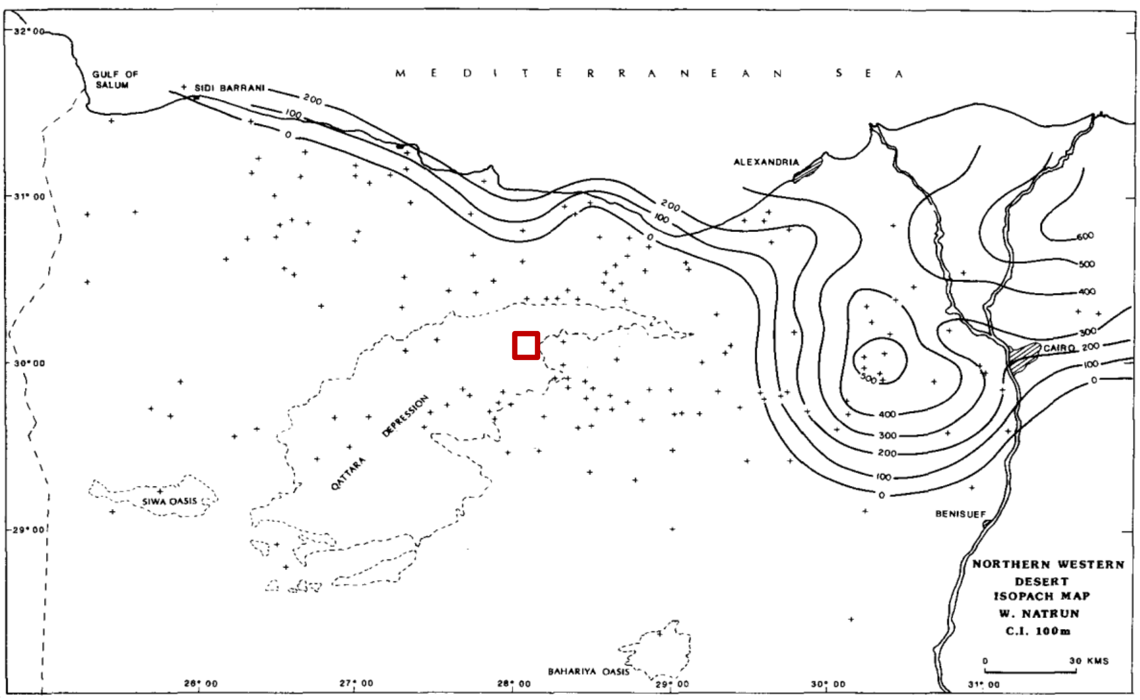

Fig. 14. Distribution and thickness of Wadi El Natrun Formation which is missing allover Qattara depression and the study area (red square), (after Hantar, 1990).

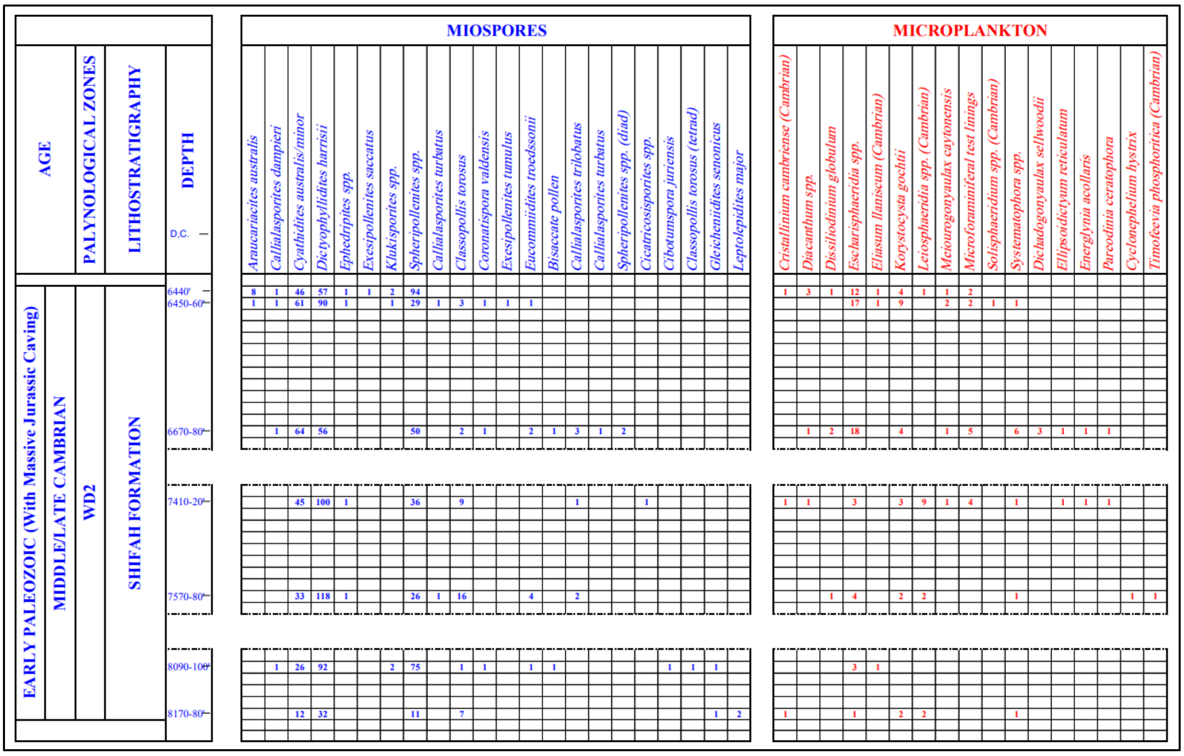

Fig. 15. The new palynology analysis for seven selected samples in sahab-1X well revealing Paleozoic age, summarised distribution chart of abundances by highest appearance of palynomorph assemblages.

5.2 Alam El Bueib Uncertainties

The presence of Alam El Bueib Formation is confirmed in the basinal area, as evidenced by both bio-stratigraphic and lithological data of Nakhil-1X well. In contrast, its occurrence in Safwa-South-1X sliver block and in the High area remains doubtful, mainly due to:

1) The facies similarity between Alam El Bueib and Kharita formations, particularly as the key intervening markers, Dahab and Alamein, are absent.
2) The absence of bio-stratigraphic analysis in Safwa-South-1X well.
3) The high potential for fossils reworking, due to the proximity of Alam El Bueib to the Jurassic-Cretaceous unconformity and Kharita to top Dahab unconformity, sometimes resulting in undefined sections.

In the Safwa-S-1X area, previous interpretations considered the Alam El Bueib Formation as absent, assigning the interval between the Masajid and Bahariya formations to the Kharita Formation (Fig. 16).

Following this approach, results in Kharita thickness of 1486 ft. (TVDT) in Safwa-S-1X well, which is more than one and a half times thicker than in Nakhil-1X well (908 ft. TVDT), despite Nakhil-1X is the type section for this interval and located in a more basinal setting (Figs. 5. 6 & 16). Moreover, seismic data show no evidence for faulting in the Safwa-South-1X well (Fig. 6) that could account for the absence of Dahab, Alamein and Alam El Bueib formations.

Based on these observations, the present study interprets Alam El Bueib Formation as partially present in the Safwa-South-1X area, with its upper part missing. The depth of top Alam El Bueib remains somewhat speculative but can be constrained within a narrow range based on Kharita Formation thickness (Kharita in Safwa-South-1X is equal to or less than Nakhil-1X) and E-logs correlation. Accordingly, the estimated thickness of Alam El Bueib in Safwa-South-1X well is 618 ft. (TVDT).

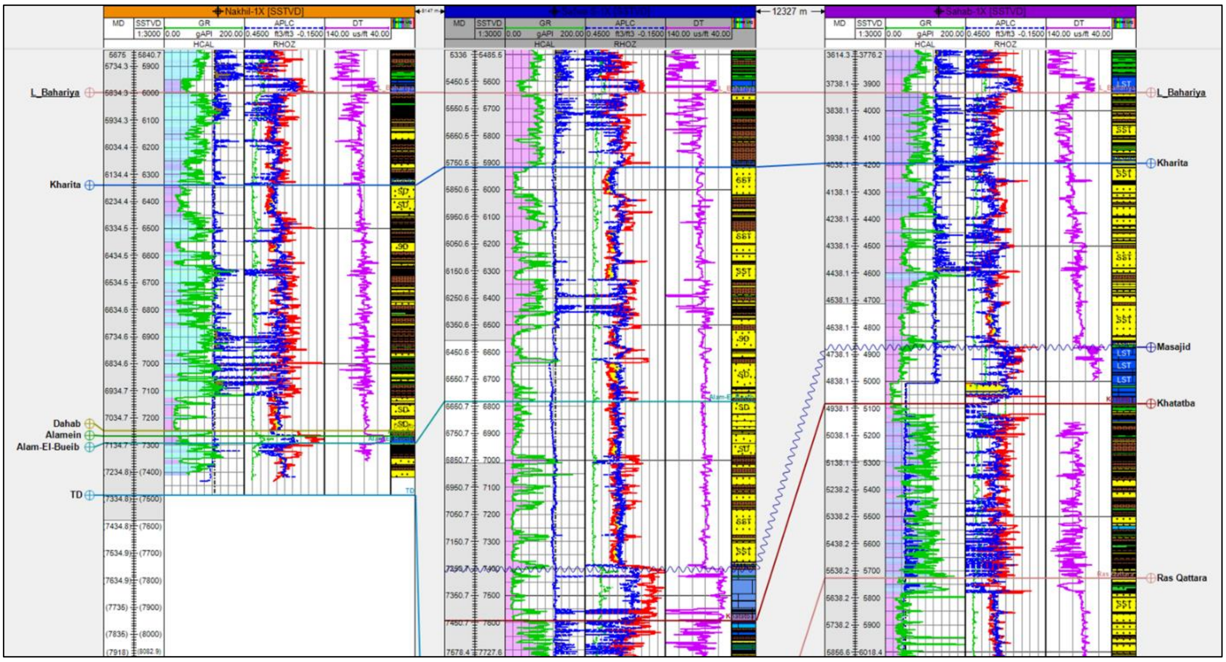

Fig. 16. Early Cretaceous correlation (flattened on top Lower Bahariya), showing the absence of Alam El Bueib, Alamein and Dahab in the High area represented by Sahab-1X well and the presence of lower part only of Alam El Bueib in Safwa-S-1X well.

On the other hand, relics of Alam El Bueib Formation may occur in the Sahab-1X well in the High area, due to the presence of an undefined interval (240 ft. thick) of sandstone and siltstone, directly overlying the Masjid Formation, the age of this interval is undetermined (Petroguide, 2010). However, the present study interprets Alam El Bueib as absent in the High area, as indicated by bio-stratigraphic & E-logs data of other wells in Sharib-Sheiba High, either inside or outside the study area. In addition, the Kharita Formation thickness in the Sahab-1X well matches its average thickness in other wells in the High. This interpretation is consistent with previous studies, including Schlumberger (1984), Hantar (1990), EGPC (1992), and Zobaa et al. (2013).

5.3 Alternative Scheme for the Late Cretaceous Sequence Subdivision

Two different stratigraphic schemes are applied for subdividing the Late Cretaceous sequence (particularly, Kharita, Lower Bahariya, Upper Bahariya and A/R "G") in the North Western Desert. These are as follows:

1- **The First Scheme**

This scheme is applied by the operating company for the wells involved in this study, in the Safwa-Sabbar Field and by other operators in the North Western Desert. In this approach, the alternating clastic and carbonate section lies below the well-known A/R "F" carbonate marker is subdivided from top to base into A/R "G1" and A/R "G2". The clastic section beneath the basal limestone marker of A/R "G2" is assigned to Upper Bahariya Member, while, the relatively cleaner sandstone interval within Bahariya Formation is designated as Lower Bahariya Member, Kharita Formation is characterized by the cleanest sandstone in the section. However, Kharita and Lower Bahariya are frequently undifferentiated due to their facies similarity (Fig. 17 & Table 2).

2- **The Second Scheme**

This approach is applied by the operator in the adjacent Neag-5 Field and by other companies in the North Western Desert. In this scheme (Fig. 18 & Table 2), the upper part of the alternated clastic and carbonate section below A/R "F" marker is designated as A/R "G" which is equivalent to A/R "G1" in the first scheme, Upper Bahariya is equivalent to A/R "G2", Lower Bahariya corresponds to Upper Bahariya in the first scheme, with the two separated by a Limestone marker called Intra-Bahariya Limestone. Kharita Formation is equivalent to the combined Lower Bahariya and Kharita of the first scheme.

This study recommends adopting the second stratigraphic scheme for all wells in the study area, because it provides units age assignments (Fig. 18) that better align with their age definition reported in the regional studies. For instance, SLB (1984) and EGPC (1992), designate Late Cenomanian age for A/R "G" Member, while the Bahariya Formation is of Early Cenomanian age, extending into the Late Albian in some areas. In contrast, the first scheme (Fig. 17) extends A/R "G2" into the Early Cenomanian and expands the age of Lower Bahariya to the Middle Albian in Sabbar-1X well, and to the Early Albian in Sahab-1X. Furthermore, the second scheme allows easier differentiation among Upper Bahariya, Lower Bahariya and Kharita units.

Moreover, under the current situation, oil production in Safwa-Sabbar Field is attributed to the Lower Bahariya, whereas in the adjacent Neag-5 Field, it comes from Upper Bahariya. This discrepancy is misleading and does not accurately reflect the actual geological setting of the area, as both fields are adjacent, sharing the same trap and reservoir. Adopting the second scheme resolves this by identifying the producing reservoir in Safwa-Sabbar Field as Upper Bahariya, in agreement with the adjacent Neag-5 Field. This alignment improves consistency and harmony between neighboring operators.

5.4 Uncertainties of Abu Roash “A’’ and Khoman Units

The presence of Abu Roash "A" (A/R "A") and Khoman units in the study area is also uncertain. In the Basinal area, this uncertainty occurs because the interval lies between Abu Roash "B" and Apollonia units in Nakhil-1X and Safwa-South-1X wells (Fig. 19) is very thin (8 ft. TVDT in Nakhil-1X and 37 ft. TVDT in Safwa-South-1X). This is likely because the area was structurally high and deposited relatively minor thickness of sediments, in addition to the strict impact of both top Abu Roash and Khoman major unconformities. These factors also increase fossils reworking, leading to poorly defined stratigraphic sections, particularly over Paleo-Highs with multiple unconformities like the study area. Further complicating matters, the two separate bio-stratigraphic analysis performed for this interval in Nakhil-X well indicated different interpretations. The first one defined it as A/R "A" Member, while the second identified it as the Maastrichtian Khoman "A" Member. These conflicting interpretations make the definition of this interval unclear and increase the chance of being interpreted alternatively.

However, the research recommends the presence of Khoman "A" Member and the absence of A/R "A" Member in the basinal area, where it unconformably overlies A/R "B" Member in Nakhil-1X and Safwa-South-1X wells. This interpretation is supported by:

1) The second bio-stratigraphic analysis of Nakhil-1X, which the researcher considers more reliable.
2) The description of Khoman unit in Nakhil-1X mud log.
3) E-Logs signature of this interval is more similar to Khoman Formation rather than A/R "A” Member, (Fig. 19).
4) The presence of two gamma-ray peaks within this interval (Fig. 19), likely indicating radioactive minerals, commonly associated with unconformity surfaces, possibly corresponding to A/R and Khoman unconformities.

On the other hand, Khoman Formation is absent in Sabbar-1X and Sahab-1X wells, which located in the structurally High area. However, it is interpreted by the operating company to be present in several

Table -2. Comparison for the first and second schemes showing the age and thickness difference in each.

First Scheme		Average Thickness ft. (TVDT)	Second Scheme		Average Thickness ft. (TVDT)
Age	Stratigraphic units		Age	Stratigraphic units	
Late Cenomanian	A/R "G1"	155	Late Cenomanian	A/R "G"	155
Early Cenomanian	A/R "G2"	230	Early Cenomanian	Upper Bahariya	230
Late Albian	Upper Bahariya	270	Late Albian	Lower Bahariya	270
Middle Albian	Lower Bahariya	230	Middle Albian	Kharita	790
Early Albian	Kharita	560	Early Albian		

wells (not included in this paper) within the High area, with limited thickness (15 ft. in average) reflecting the significant effect of differential erosion.

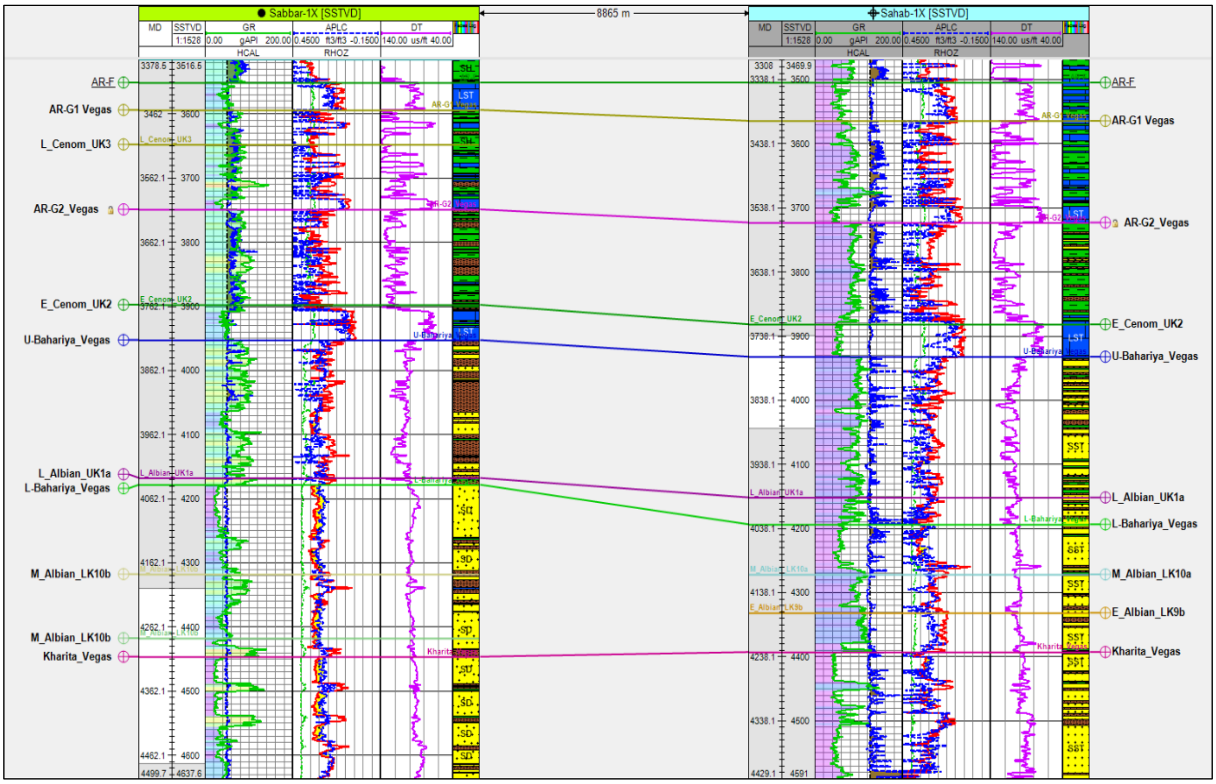

Fig. 17. The first stratigraphic scheme (flattened on top A/R "F"). Bio-zones are displayed as formation tops.

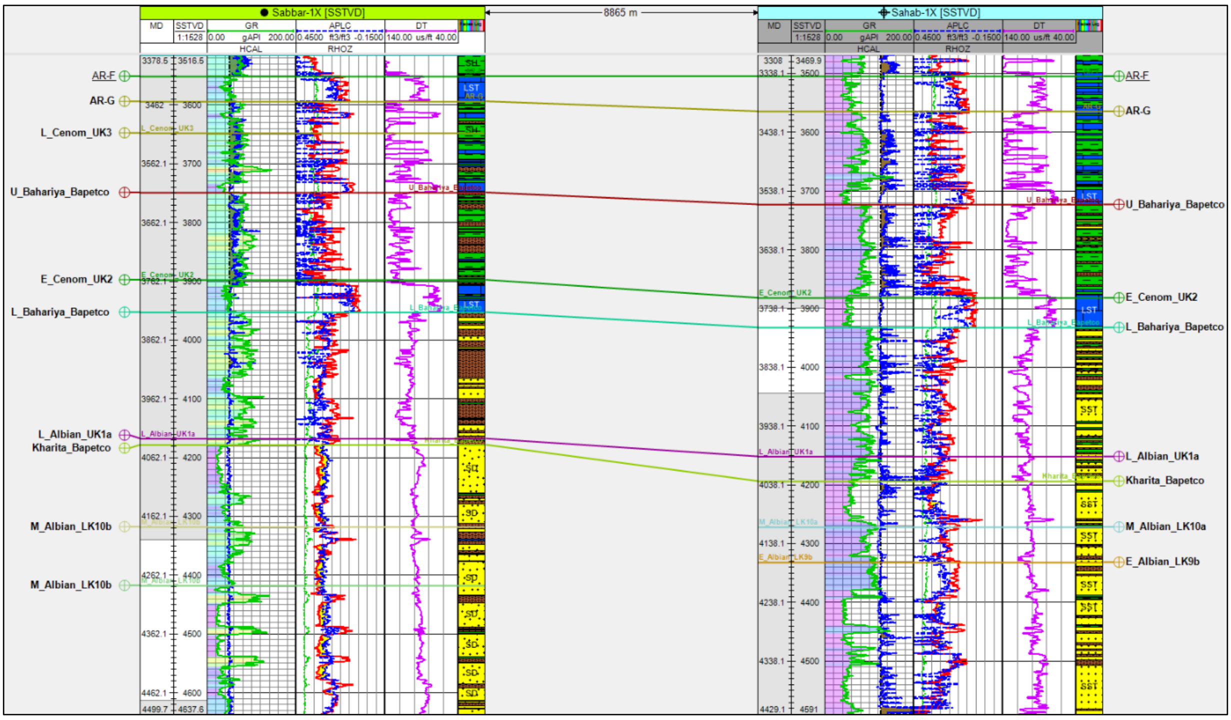

Fig. 18. The second scheme (flattened on top A/R "F"). The Bio-zones are displayed as formation tops.

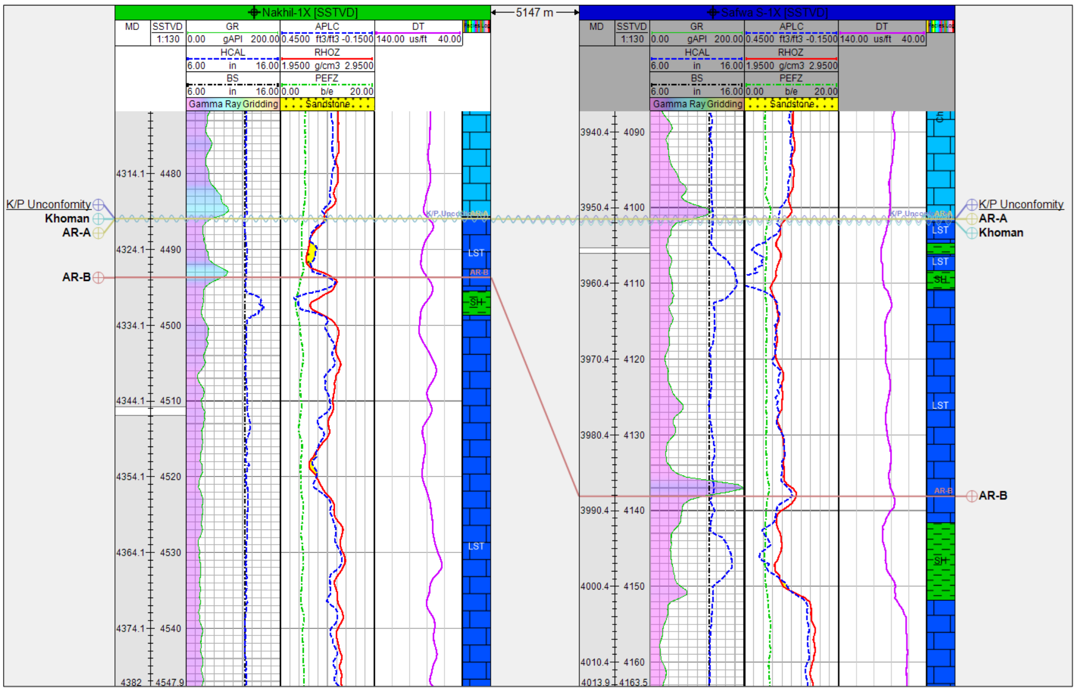

Fig. 19. Correlation of the stratigraphic interval under debate, to interpreted either as Abu Roash "A" or Khoman.

6. Implications for the Petroleum System and Play Concepts

This study provides new insights into the petroleum system, tectono-stratigraphic framework and play concepts of the area. With the refined definition of Paleozoic units in the area, the scope of play concepts may be expanded to include new regional contexts, requiring an evaluation of their resource potential.

The adoption of an optimized subdivision scheme for the Late Cretaceous sequence, along with a harmonized reservoir nomenclature across adjacent fields, improves the understanding of reservoir characteristics and distribution. This alignment not only facilitates technical communication between operators but also supports enhanced hydrocarbon recovery. In particular, it enables recommended collaborative development initiatives, such as joint unitization agreements, as the hydrocarbons extend across concession boundaries (Safwa-Sabbar and Neag-5 fields).

Moreover, generating sub-crop maps for top Dahab and Abu Roash unconformities are essential to identify the presence and distribution of Alam El Bueib and Abu Roash units. This is significant because Alam El Bueib is a potential reservoir in the region, and Abu Roash members are among the main reservoirs in the adjacent Abu Ghardig Basin. Such maps can provide valuable guidance for optimizing future exploration targets in the area.

Finally, accurate estimation of eroded sediments thickness, especially over Paleo-Highs is crucial, for constructing reliable burial history (Fig. 20) and 1D basin model to assess the maturity of key source rocks which could influence the decision to proceed with or abandon exploration in such areas. The thickness of the missing units was estimated by correlation with nearby more complete wells. The results indicate that the Early Cretaceous missing units (Dahab, Alamein and Alam El Buieb) reach about 1,400 ft. in the High area (Sahab-1X well), and around 790 ft. (Dahab, Alamein, and the top part of Alam El Buieb) in Safwa-S-1X well (Figs. 7, 9 & 16). For the Late Cretaceous, the section from top Khoman to the upper part of A/R "E" are absent (Figs. 7 & 10) by roughly 2000 ft. in the High area (Sahab-1X and Sabbar-1X wells), increasing to about 2400 ft. in other wells where the missing interval extends to the upper part of A/R "G" (Fig. 10). Whereas, In the basinal area, the absence is about 1000 ft., covering most of Khoman, A/R "A" and possibly the top part of A/R "B" (Figs. 7 & 10). However, these thickness estimates could be significantly greater if correlated with deeperbasinal wells, particularly for Khoman Formation.

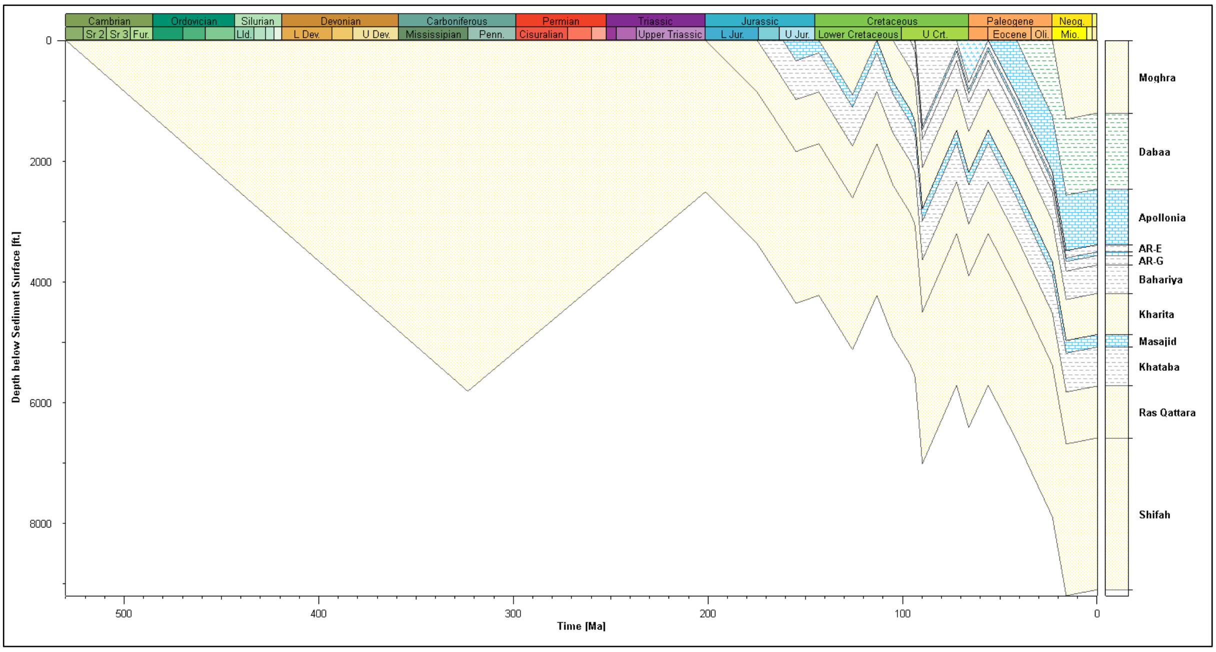

Fig. 20. Burial history for Sahab-1X well in the structural High area, reflection the effect of major unconformities (5 at least).

Conclusion

• The misinterpretation of formations is not only about changing their age and nomenclature, it has reaching consequences. It can adjust the geological understanding including: structural evolution, tectono-stratigraphic framework, and play concepts, ultimately influencing future exploration and development strategies in such areas.

• This study addresses resolving uncertainties regarding the age and definition of the Paleozoic and Jurassic units, introduces alternative subdivision for the Late Cretaceous sequence and clarifies the presence of Alam El Bueib and Khoman formations in previously un-recognized areas, thus expanding their known geographic distribution.

• The re-evaluation of the previous bio-stratigraphic data from Sahab-1X well, reveals that intervals previously assigned a Jurassic age were, in fact, of Paleozoic age. palynological analysis confirms these intervals belong to the Middle to Late Cambrian Shifah Formation.

• The findings underscore the importance of adopting consistent stratigraphic scheme for subdividing Kharita, Lower Bahariya, Upper Bahariya, and A/R "G" units across the region. This recommended approach better aligns with local bio-stratigraphic data, regional age assignments and the practice of neighbor operators. It enables clearer differentiation among Upper Bahariya, Lower Bahariya and Kharita units and harmonizes reservoir definitions.

• The research, concludes that A/R "A" Member, previously identified in some interpretations, is more accurately classified as Khoman Formation, supporting the revised tectono-stratigraphic model.

• The amount of missing units associated with each unconformity were estimated through the correlation with nearby more complete basinal wells. This is critical for accurate burial history building and source rock maturity assessment in the study area. The missing sections in the study area generally increase from the southern Basinal area to the northern High area. Moreover, the sub-crop maps provide insights about the distribution of different units beneath the unconformities which directly optimize future drilling targets.

Recommendation

Based on the findings of this study, the following recommendations are proposed:

1. While, conducting bio-stratigraphic analysis in exploration wells is crucial, but it is not enough on its own. It is equally important to integrate the regional and local stratigraphic framework, schemes, formations ages and definitions to reduce misinterpretations of rock ages, particularly in areas with significant uncertainties such as Paleo-Highs affected by multiple unconformities.

2. Besides, in-depth comprehensive review and open discussions for bio-stratigraphic results between service and operating companies is mandatory. This collaborative approach ensures that geological concepts are properly integrated and discrepancies are resolved.
3. Furthermore, adopting one regional bio-stratigraphic and lihto-stratigraphic schemes across companies working in the same basin at least is imperative to avoid inconsistent age assignments and formations definitions and ensure valid regional geological work.
4. Neighboring companies producing from the same reservoir should unify their stratigraphic terminology and conduct regular technical discussions. Standardization improves consistency, facilitates communication, reservoir understanding, and supports future activities like unitization agreements which is highly recommended between Safwa-Sabbar and Neag-5 fields for better reservoir management, optimized operations and resources recovery at lower costs.
5. Future research should employ other methods like apatite fission track, vitrine reflectance and sonic log data to estimate eroded thickness in Paleo-Highs and sharing best practices.
6. Finally, comprehensive regional studies for the Paleozoic in the North Western Desert are highly needed to better understand their distribution, geological controls, and hydrocarbon potential.

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References

Bevan, T. G., & Moustafa, A. R. (2012). Inverted rift-basins of northern Egypt. In Regional geology and tectonics: Phanerozoic rift systems and sedimentary basins (pp. 482-507). Elsevier.

Bosworth, W., El-Hawat, A. S., Helgeson, D. E., & Burke, K. (2008). Cyrenaican “shock absorber” and associated inversion strain shadow in the collision zone of northeast Africa. Geology, 36(9), 695-698.

Dahi, M., & Shahin, A. N. (1992). Paleozoic rocks distribution and hydrocarbon potential in the Western Desert, Egypt. In 11th Petroleum Exploration and Development Conference, Cairo.

Dolson, J. C., Shann, M. V., Matbouly, S., Harwood, C., Rashed, R., & Hammouda, H. (2001). The petroleum potential of Egypt.

Dolson, J. C., Atta, M., Blanchard, D., Sehim, A., Villinski, J., Loutit, T., & Romine, K. (2014). Egypt’s future petroleum resources: a revised look into the 21st century.

Egyptian General Petroleum Corporation. (1992). Western Desert oil and gas fields: A comprehensive overview. Cairo.

El Gazzar, A. M., Moustafa, A. R., & Bentham, P. (2016). Structural evolution of the Abu Gharadig field area, northern Western Desert, Egypt. Journal of African Earth Sciences, 124, 340-354.

El Emam, A., Dishopp, D., & Dunderdale, I. (1990). The structural setting of the central Western Desert, Egypt. In 10th Egyptian General Petroleum Corporation Seminar (Vol. 2, pp. 30-70).

El Redini, N. A. H. (2016). Seismic data interpretation for hydrocarbon potential, East Ghazalat onshore area, Abu El Gharadig Basin, Western Desert, Egypt (Master’s thesis). Cairo University, Cairo, Egypt.

El Redini, N. A. H., Bakr, A. M. A., & Dahroug, S. M. (2017). Seismic data interpretation for hydrocarbon potential, for Safwa/Sabbar field, East Ghazalat onshore area, Abu Gharadig basin, Western Desert, Egypt. NRIAG Journal of Astronomy and Geophysics, 6(2), 287-299.

Google Maps. https://www.google.com/maps

Hanter, G. (1990). North Western Desert. In R. Said (Ed.), The geology of Egypt (pp. 293–319). Rotterdam: A. A. Balkema.

Hassan, S. (2018). Depositional environment analysis of the Lower Cenomanian Bahariya Formation, East Ghazalat Field, Western Desert, Egypt (Master’s thesis). Cairo University, Cairo, Egypt.

Hassan, S. & Darwish, M. (2018). Late Albian–Early Cenomanian Basin Evolution Using High Resolution Sedimentary Facies Prediction of Abu Gharadig Pericratonic Basin of the North Western Desert, Egypt and its Hydrocarbon Habitat. Egyptian Journal of Geology, 62(1), 83-101.

Hassan, S., Darwish, M., Tahoun, S. S., & Radwan, A. E. (2022). An integrated high-resolution image log, sequence stratigraphy and palynofacies analysis to reconstruct the Albian–Cenomanian basin depositional setting and cyclicity: Insights from the southern Tethys. Marine and Petroleum Geology, 137, 105502.

Ibrahim, M., Darwish, M., & Sakran, S. Oil-Bearing Tectono-Stratigraphic Sequences of East Tiba Sub-Basin: A Case Study from North Western Desert, Egypt.

Moustafa, A. R. (2008). Mesozoic-Cenozoic basin evolution in the northern Western Desert of Egypt. Geology of East Libya, 3, 29-46.

Moustafa, A. R. (2020). Mesozoic-cenozoic deformation history of Egypt. In The geology of Egypt (pp. 253-294). Cham: Springer International Publishing.

SCHLUMBERGER (1984). Well evaluation conference: Geology of Egypt. 1-64.

Zobaa, M. K., El Beialy, S. Y., El-Sheikh, H. A., & El Beshtawy, M. K. (2013). Jurassic–Cretaceous palynomorphs, palynofacies, and petroleum potential of the Sharib-1X and Ghoroud-1X wells, north Western Desert, Egypt. Journal of African Earth Sciences, 78, 51-65.

Unpublished Internal Reports

Ahmed, S., BIOSTRATIGRAPHER CONSULTANT, (2014). Nakhil-1X selected intervals: Micro-palaeontological analysis (PETROSAFWA Internal Report, pp. 1-4).

Ahmed, S., BIOSTRATIGRAPHER CONSULTANT, (2014). Sahab-1X selected intervals: Micro-palaeontological analysis (PETROSAFWA Internal Report, pp. 1-4).

HBS International Egypt LTD (2004). SD8-1-ST final well report.

Petroguide Consultancy Surfaces (2010), Sahab-1X biostratigraphic and lithostratigraphic study, (VEGAS OIL & GAS S.A. Internal Report, pp. 1-26).

Petroguide Consultancy Surfaces (2011), Nakhil-1X biostratigraphic and lithostratigraphic study, (VEGAS OIL & GAS S.A. Internal Report, pp. 1-26).

Petroguide Consultancy Surfaces (2011), Sabbar-1X biostratigraphic and lithostratigraphic study, (VEGAS OIL & GAS S.A. Internal Report, pp. 1-26).

VEGAS OIL & GAS S.A. (2010). Sahab-1X final geological report (pp. 1-31).

VEGAS OIL & GAS S.A. (2011). Nakhil-1X final geological report (pp. 1-28).

VEGAS OIL & GAS S.A. (2011). Sabbar-1X final geological report (pp. 1-28).

PETROSAFWA (2013). Safwa-South-1X final geological report (pp. 1-59).