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Subdividing a Cretaceous Carbonate Reservoir in the East Mediterranean Sea, Egypt, Based on Petrographical Characteristics: A Case Study

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ABSTRACT

Reservoir studies necessitate a consistent and repeatable classification of carbonate lithofacies, serving as a fundamental input for constructing depositional, diagenetic, and reservoir models. Traditionally, the Dunham and Folk Systems have been relied upon to fulfill this requirement. In the Cretaceous carbonate reservoir of the Zohr field, the reservoir is subdivided into four sub-reservoirs based on biostratigraphic and sedimentological analyses. These reservoir levels, from top to bottom, are designated as Level 1, Level 2, Level 3, and Level 4. These units exhibit variations in thickness, facies, and petrophysical properties, often leading to differences between wells. In many instances, it is challenging to correlate the log patterns observed in these units. This is due to lateral variations in depositional facies, syn-depositional changes and post-depositional diagenetic processes. This study investigates these Cretaceous-aged carbonate lithofacies in the Zohr field by employing the highly detailed and comprehensive approach of petrographical analysis which allows for a more accurate classification of these rocks compared to conventional methods. It examines a spectrum of synthetic rock textures, natural lithologies, and thin section textures derived from core samples, side-wall cores, and ditch cuttings. As a result, the outcomes of this petrographical analysis have helped in refining the present reservoir boundaries. The modified boundaries derived from petrographic analysis have been adopted, thereby facilitating the development of more realistically constrained depositional, diagenetic, and reservoir models. Furthermore, the results have been utilized to create texture and porosity curves, enabling a detailed and accurate correlation among different wells and reservoir levels in the Zohr field.

Introduction

The primary objective of this study is to analyze and interpret the internal sedimentary features and microfacies of Cretaceous carbonate reservoirs using core data through petrographical analysis. This detailed analysis aims to better characterize the boundaries of these reservoirs, improving upon the interpretations derived from seismic and stratigraphic data. The study selected Well-A as a case due to its exceptional thickness and comprehensive representation of the Cretaceous carbonate section among the wells in the Zohr field. Petrographic analysis was conducted on thin sections prepared from core samples (both vertical and horizontal) and ditch cuttings. Core-log integration and petrographic analysis were the key tools employed to characterize the Cretaceous carbonate reservoir units. The findings from these analyses were then applied to other wells within the Zohr field. The Cretaceous reservoirs exhibit very good to excellent reservoir properties, with evidence of fractures and karst events **(Tisljar *et al.,* 2002)**. The geometry of the Cretaceous reservoir comprises a shallow-marine carbonate platform divided into four main levels. The uppermost level, Level 1; includes Tertiary shallow water and pelagic sediments. The top of the Cretaceous reservoir in the Zohr field lies beneath the salt sealing of the Rosetta Formation. The stratigraphy reflects the evolution of a typical carbonate platform, featuring various depositional environments ranging from reef buildup dominated by Rudists to lagoon and tidal flat domains, where supratidal to intertidal deposits predominate. Patch reef deposits occasionally alternate with these environments. The tidal flat domain is characteristic of Level 4, the lowermost part of the reservoir, while lagoonal and reef environments dominate the more widespread areas in Levels 3 and 2. Additionally, pelagic deposits in Level 1 have been identified, representing drowning phases of the carbonate platform during the uppermost Cretaceous and Tertiary periods. These deposits consist of marls, marly limestones, and pelagic carbonates characterized by poor reservoir properties (Fig. 1).

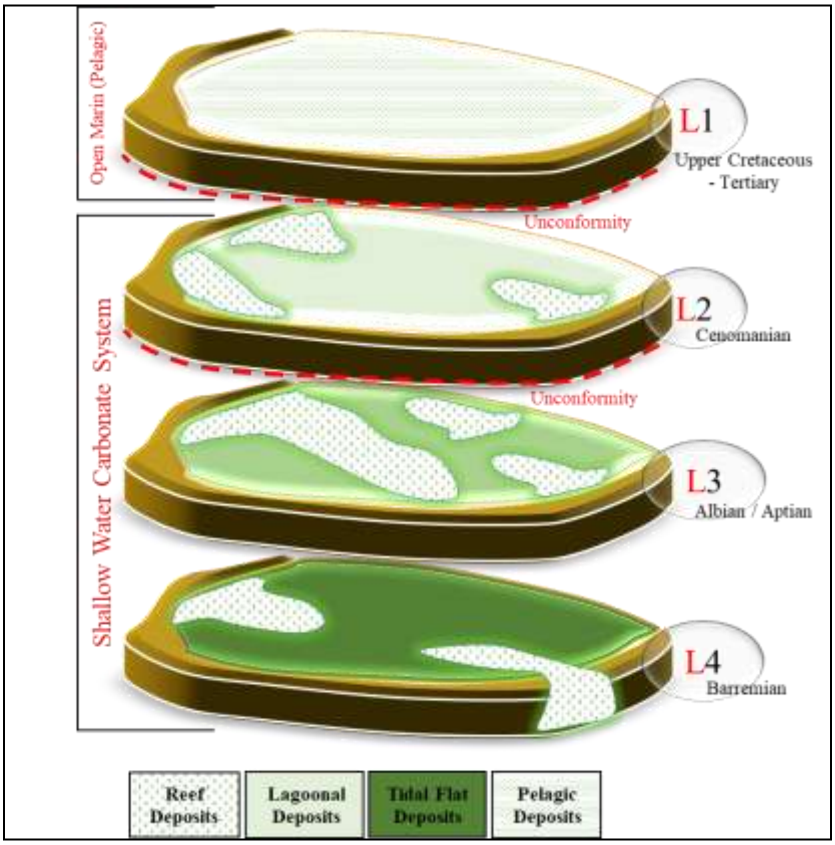

Fig. (1): Zohr reservoir description.

Geological Setting

A high-quality reefal carbonate buildup was unexpectedly discovered in close proximity to the major Nile delta siliciclastic depositional system. Given that reef and siliciclastic depositional conditions rarely coexist, the discovery of the Zohr field posed a significant challenge, located near the borders of the Shorouk block. The geological evaluation and tectonic history of the Eratosthenes carbonate platform are pivotal in understanding the existence and discovery of the Zohr field. The Eratosthenes continental block constitutes a geological province situated to the west of the Levantine Basin **(Esestime P. *et al.*, 2016; El-Gendy *et al.*, 2023).** Initially part of the broader Eratosthenes platform, the Zohr structure now represents its fault-bounded southernmost portion, stemming from the onset of the collisional phase during the Messinian age **(Hawie *et al.*, 2013)**. While various models exist for the paleo-tectonic evolution of the East Mediterranean Basin, it is widely accepted that rifting in the Levantine region commenced during the early Triassic and persisted until the middle Jurassic period. The Eratosthenes continental block is believed to have detached from the North African continental margin during the early Mesozoic, subsequently undergoing collisional deformation during the Pliocene-Pleistocene period. These considerations help define the Eratosthenes block as an isolated carbonate platform, detached from the continent for much of its Mesozoic tectono-stratigraphic evolution **(Tassy *et al.*, 2015; Barakat *et al.*, 2021)**. In terms of play risk assessment, it is essential to consider possible variations in subsidence rates within the Eratosthenes Zohr Block, potentially leading to differential sedimentation rates (Fig. 2).

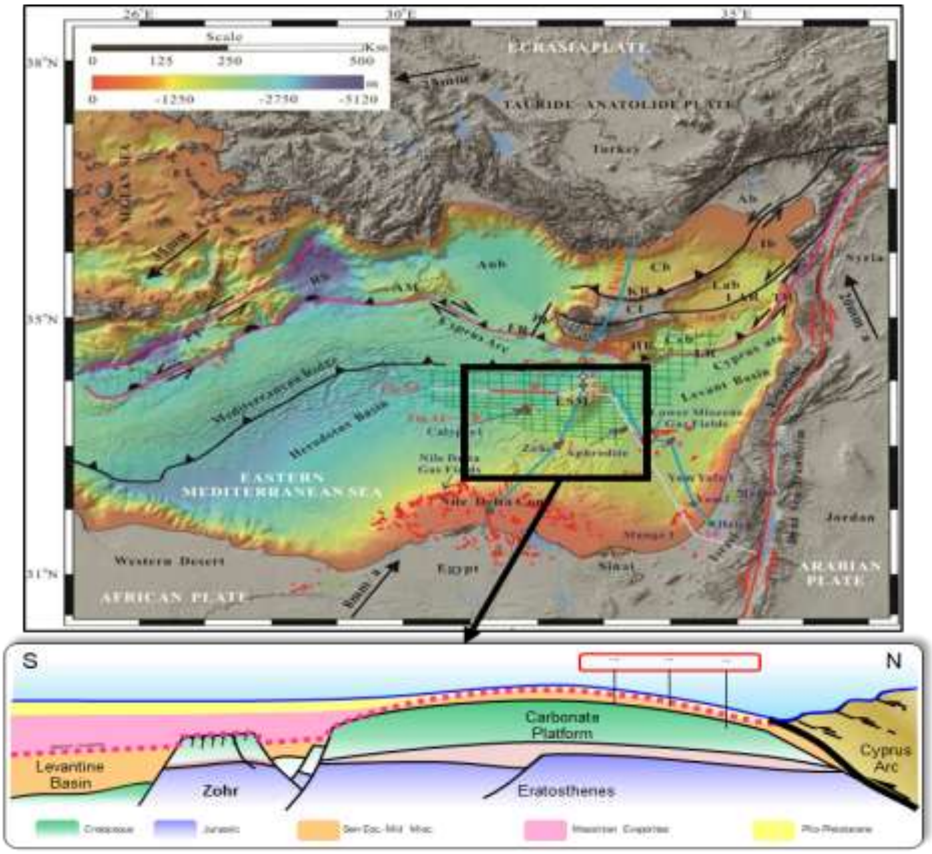

Fig. (2): Regional Framework: Zohr-Eratosthenes Relationships **(After Montadert *et al.*, 2014; Aksu *et al.*, 2005b; Tassy *et al.*, 2015)**.

The Eratosthenes-Zohr block emerged as an isolated intra-oceanic entity from the early Jurassic period onward. Consequently, it experienced a higher subsidence rate compared to the Eastern Levantine margin due to lithospheric cooling during the late-post rifting phase **(Barakat and Dominik 2010; El-Ata *et al.*, 2023; El-Gendy *et al.*, 2023)**.

In contrast to the Eastern Levantine margin, which contains siliciclastic sequences of continental origin interbedded within most Mesozoic carbonate sequences, the Eratosthenes block did not receive any siliciclastic input. The primary reservoir zone in the Zohr field belongs to the Cretaceous period.

Materials and Methods

Petrographical analysis was conducted on 70 samples, including core samples, ditch cuttings, and thin sections, collected from different wells within the Zohr field. These samples were systematically classified according to reservoir zonation (L1, L2, L3, and L4) to establish distinct petrographical patterns for each zone. The results of the petrographical analysis of thin sections were utilized to construct a Point Count Porosity curve, providing comprehensive characteristics for each reservoir zone. This analysis played a crucial role in refining the correlation between wells, especially in areas where delineating reservoir boundaries posed challenges due to issues such as caving and aging. Thin section samples were meticulously described in terms of their biostratigraphy, facies, and texture content, with point count porosity determined for each sample. Results of this petrographical analysis were applied on the case study, Well-A; due to its complete Cretaceous aged section. The definition of facies and associated depositional environments is usually carried out using compositional criteria **(Dunham, 1962; Folk, 1959 and 1962; Embry and Klovan, 1972; Wilson, 1970 and 1974; Shalaby *et al.*, 2022; Saadawi *et al.*, 2023; Abdullah *et al.*, 2021b)**. The reference depositional model currently adopted for Zohr field, illustrated in Fig. (3), is derived from a combination of the schemes proposed by **Leinfelder and Schmid (2000)** and **Boudagher-Fadel (2008)**. These schemes depict the typical distribution of reef builders and microbial-related elements across contiguous settings, as well as the common distribution of large benthic foraminifera in Cretaceous carbonate systems. All defined depositional facies from the available samples were grouped into a classification Scheme following **Dunham (1962)** that modifications of **Embry and Klovan (1971)**, as shown in Table (1).

This hierarchical scheme was constructed to encompass associations, groups, and types of facies representative of the inner, shallower environments to the outer, relatively deeper environments within the carbonate system. The reference depositional model, based on the facies analysis, represents a typical Cretaceous shallow-marine water, ramp-like carbonate system. It can be subdivided into the following zones:

- Inner zone: Affected by seasonal tides, characterized by local algal mats, tidal channels, shoals, and lagoons.
- Marginal zone: Marked by Rudist banks and patch reefs.

- Outer zone: Presumed to be dominated by reworked slope deposits.

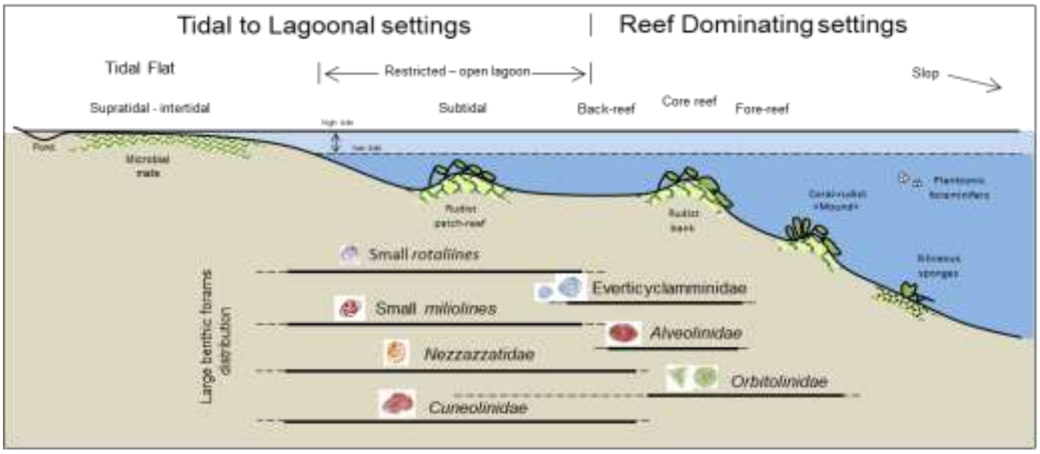

Fig. (3): Reference depositional model adopted for Zohr field, derived and modified from a combination of the schemes by **Leinfelder and Schmid (2000)** and **Boudagher-Fadel (2008)**.

Facies Association		FACIES GROUP	FACIES TYPE
Tidal Flat		Supratidal to intertidal	Microbial "stromatolite-like" bindstone (algal marsh/pond)
		Intertidal	Fenestral peloidal WKST
			Coated grain peloidal GRST/PKST (tidal channel)
		Subtidal	Intra-peloidal PKST
			Skeletal PKST and WKST
			Calcareous marls and marly limestones
Lagoon	Restricted Lagoon	Supratidal to intertidal	Fenestral peloidal WKST
		Intertidal to subtidal	Oncoidal PKST
		Subtidal	Peloidal skeletal PKST
	open lagoon punctuated by rudist patch-reefs	Intertidal	Intra-peloidal PKST
		Subtidal	Skeletal PKST and WKST
		Patch-reef related	Rudist BDST
			Bioclastic GRST/PKST and RDST
Reef-related		Back-Reef	Bioclastic PKST and FLST with Rudist
		Core-Reef	Rudist BDST
		Gen. Reef-related	Bioclastic GRST/PKST and RDST
			Coated grain GRST and PKST (inter-biohermal facies)
		Fore-reef	Bioclastic GRST and RDST
Slope to Pelagic		slope	Breccia
			Skeletal MDST and WKST

Table (1): Facies classification scheme for Zohr field. (MDST: Mudstone; WKST: Wackestone; PKST: Packstone; GRST: Grainstone; FLST: Floatstone, RDST: Rudstone). Following **Dunham (1962)** and modifications by **Embry and Klovan (1971)**

Criteria were adopted to differentiate between these two environments and to precisely locate the facies within the depositional model, correlating them with other facies types along the studied sequence. Reef-related sediments interbedded with fine to medium-grained skeletal and intra-peloidal lagoonal deposits (subtidal facies) are identified as patch-reef facies punctuating the lagoonal setting **(El-Gendy *et al*., 2017 and 2022)**. Conversely, where reef-related sediments are interbedded with coarse-grained intra-bioclastic deposits, they are interpreted as facies deposited in the marginal area (Fig. 4).

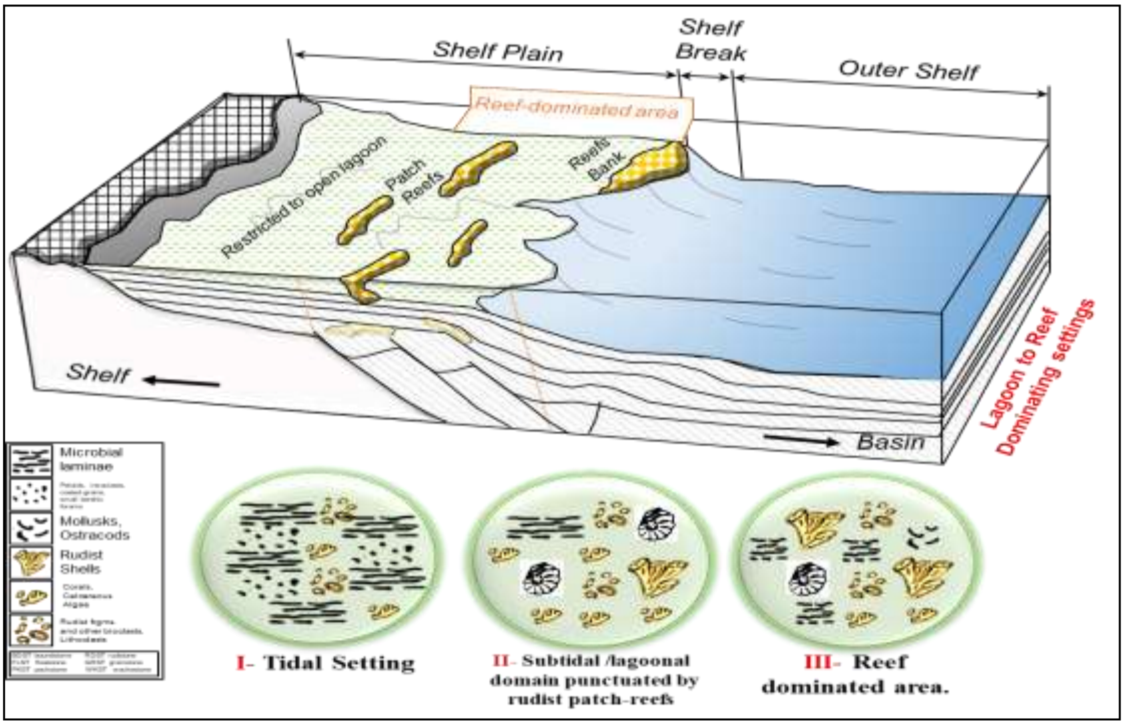

Fig. (4): Different facies stacking patterns observed along the Cretaceous reservoir section related to different peculiar depositional domains. Stacking pattern, I is typical of the Level 4; II and III are common in the units Level 2 and Level 3, modified after **Tucker, 1990.**

Results

Petrographical analysis of Level 1:

Level 1 (L1), the upper unit, extends from the upper Cretaceous to the Tertiary period. It exhibits moderate to good porosity and low to moderate permeability. This unit primarily comprises marly and carbonate sediments, which can be either reworked or in situ. Planktonic foraminifera are abundant in this unit, indicating deposition in an open marine/pelagic setting. Generally, L1 exhibits facies types commonly found at the base of the Messinian salt sequence and is often associated with the onset of the Mediterranean salinity crisis, which occurred during the upper part of the Messinian stage. Level 1 (L1) has been encountered in all studied wells, although its thickness varies between wells. The thickness of L1 increases as the basin descends towards the south of Zohr field. This downward inclination facilitates the accumulation of pelagic sediments, such as marl and carbonate, within this unit.

Petrographical and scanning electron microscope analyses, of the studied wells (Fig. 5) reveal that the marl facies of L1 suggests a pelagic depositional setting at this reservoir level, indicating deposition in a deep-water environment. However, the presence of other minor facies within L1 suggests the occurrence of shallower depositional settings. These facies include:

- Diatomaceous marls and calcareous diatomites: Micro-porous, exhibiting an assemblage of fine, delicate diatomite skeletons. This lithofacies was deposited under lagoonal settings.
- Marls and marly limestone: Pyrite and detrital quartz grains are detected. The increase in argillaceous content is due to the abundance of micro-fossils, indicating increased water circulation and a relatively deepening of the environment.
- Recrystallized carbonates and breccia: A massive to breccia texture with severely recrystallized carbonates, locally dolomitized, with clasts of shale, scattered planktonic foraminifera of Tertiary age, and patches of replacive silica (chalcedony) are present.
- Interbedded grainy and massive shallow-marine water carbonates, including peritidal facies and reef-related deposits, are also present.
- Recrystallized limestone and clasts of reworked calcareous mudstones with planktonic foraminifera are recorded.
- Evaporites and claystone: At the base of the Messinian salt, an evaporitic mixed with claystone are detected within this reservoir level, consisting of halite, anhydrite, followed by claystone interpreted as deposited within subtidal restricted and hypersaline conditions.
- Fossiliferous limestone: Consists of Wackestone rich in fossils. A polygenic carbonate breccia made up of clasts of different carbonate facies, in a dolomitized micritic groundmass yielding planktonic foraminifera of a marginal lagoon setting, is detected.
- Claystone: Comprised of fossiliferous claystone/dolomitic claystone with Packstone and Wackestone texture, yielding planktonic foraminifera that may have been deposited within low-energy outer neritic to bathyal basin settings with high intragranular porosity and, in place, low micro-porosity.

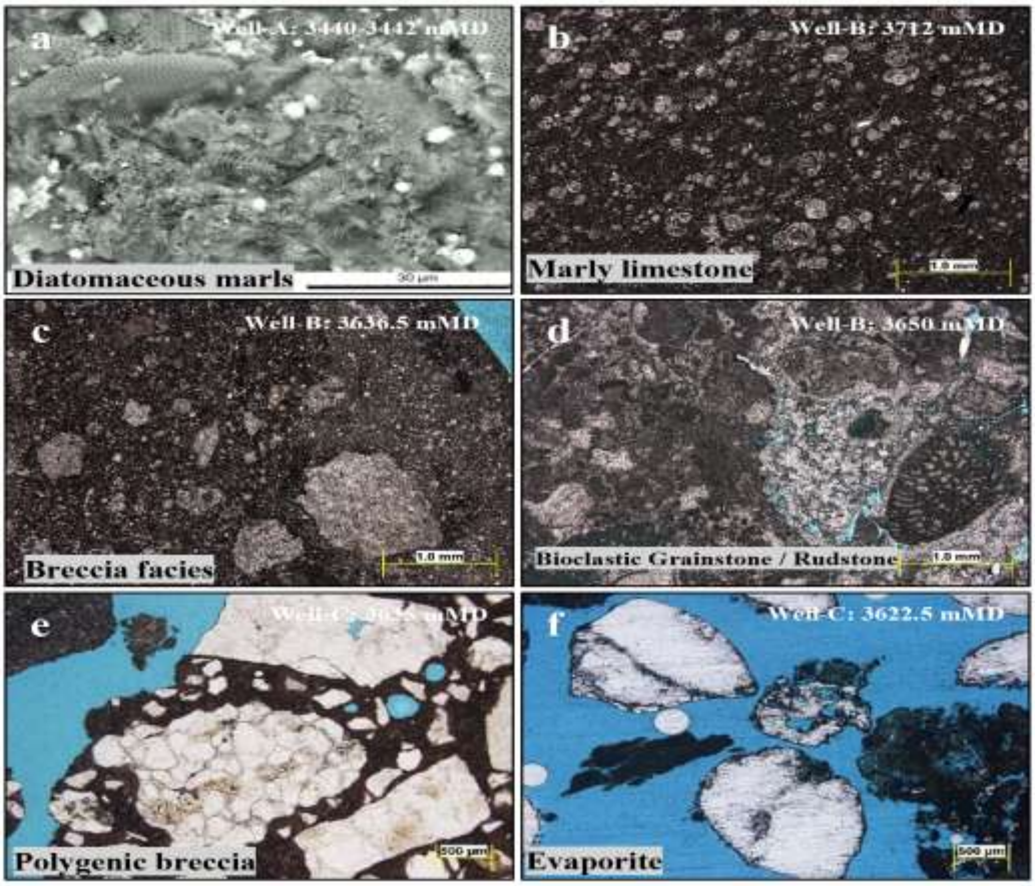

Fig. (5): Photomicrographs of L1 facies, Zohr field. a: Diatomaceous marls, b: Marly limestone, c: Breccia facies, d: Bioclastic Grainstone / Rudstone, e: Polygenic breccia, f: Evaporite**.**

Petrographical analysis of Level 2:

In the northern part of Zohr field, L2 is suggested to have been deposited under tidal flat to lagoonal environments, occasionally dominated by reef settings. Conversely, in the southern part of the field, reef settings are more prevalent. Generally, L2 is characterized by irregular cavities filled with dark micrite, as well as dissolution-enlarged fractures filled with dark micrite. L2 can be further subdivided based on facies into:

- Interbedded microbial stromatolite-like Bindstone with fenestra-like cavities, intra-bioclastic and peloidal skeletal Packstone, and Grainstone/Packstone that seems to belong to tidal flat depositional settings.
- Faintly laminated to laminated micro-breccia, comprised of intra-clasts of Mudstone and Wackestone rich in planktonic foraminifera, with the presence of glauconite, pyrite, and scattered phosphatic elements. This component and texture suggest a reworked condensed section, deposited in an open marine to pelagic environment.

- Shallow-water carbonates consisting of interbedded lagoonal and reef-related sediments. Skeletal and bioclastic Packstone and Wackestone with small benthic foraminifera and calcareous algae are associated with intra-peloidal Packstone and, locally, microbial Bindstone. Reef-related facies comprise bioclastic Grainstone and Rudstone with coarse Rudist fragments, orbitolinids, microbial encrusting forms, and corals (Fig. 6).

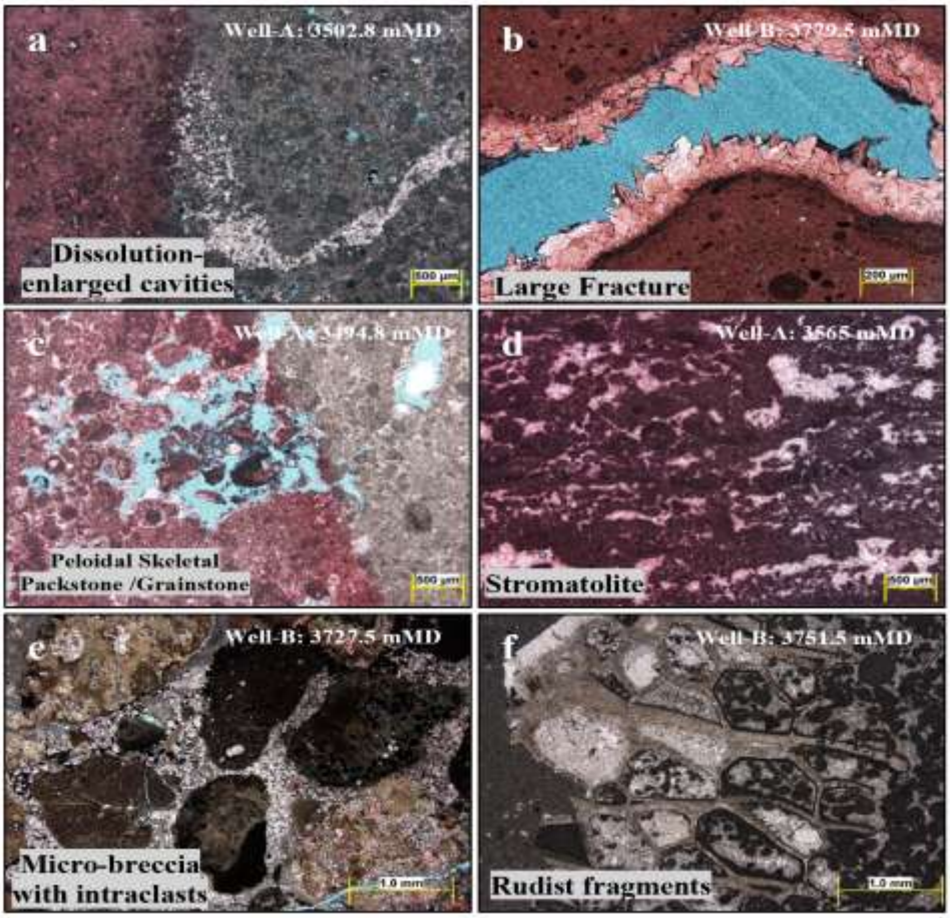

Fig. (6): Photomicrographs of L2 facies, Zohr field. a: Dissolution-enlarged cavities, b: Large Fracture, c: Peloidal Skeletal Packstone /Grainstone, d: Stromatolite, e: Micro-breccia with intraclasts, f: Rudist fragments.

Petrographical analysis of Level 3:

Level 3 (L3) is predominantly characterized by coarse-grained bioclastic Packstone, Grainstone/Rudstone, and Floatstone, representing the main facies types. These sediments contain fragments of reef-building organisms, primarily Rudists, with subordinate occurrences of corals, oysters, calcareous algae, and encrusting forms. The composition of L3 points towards reef-related facies. Specifically, these observed carbonates are developed in a restricted to open lagoon setting punctuated by Rudist patch-reefs. From the perspective of reservoir quality and continuity, L3 is considered the most favorable reservoir among others of Cretaceous age in Zohr field.

Primary pores, including intergranular and fenestral-related pores, are often enlarged by dissolution processes and are associated with secondary pores such as molds, vugs, fracture-related pores, and micro-pores due to dolomitization, defining a highly efficient dual-porosity system. This interval comprises interbedded massive limestone primarily composed of micro-crystalline calcite, along with a porous limestone exhibiting highly connected moldic and vuggy pores. Additionally, isolated moldic and vuggy porosities are scattered throughout. Dolomitized breccia is also well recognized within this interval. The pores types in L3 occur in the form of fenestral, intergranular, intra-moldic, moldic, and micro-pores, which are commonly associated with reefal settings. The porosity values are notably very good in this unit (Fig. 7).

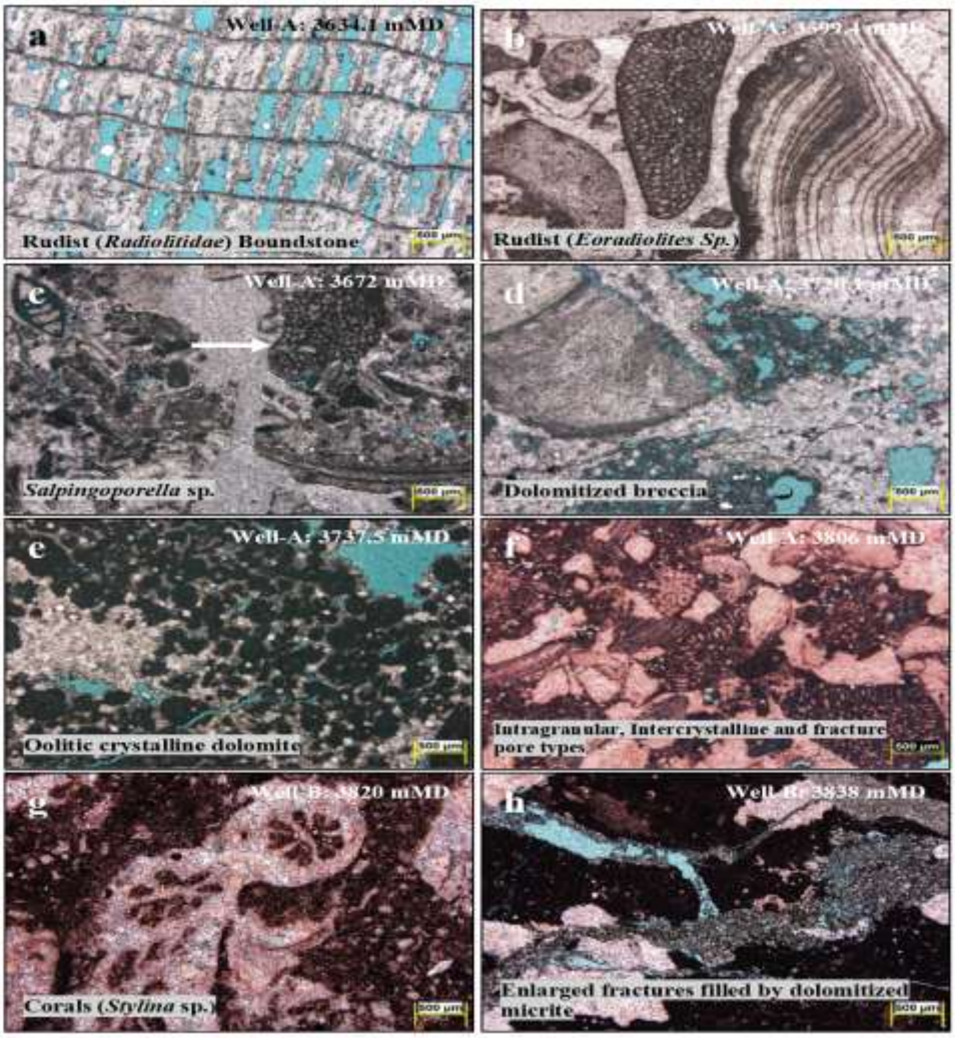

Fig. (7): Photomicrographs of L3 facies, Zohr field. a: Rudist (*Radiolitidae*) Boundstone, b: Rudist (*Eoradiolites* Sp.), c: *Salpingoporella* Sp., d: Dolomitized breccia, e: Oolitic crystalline dolomite, f: Intragranular, Intercrystalline and fracture pore types, g: Corals (*Stylina* Sp.), h: Enlarged fractures filled by dolomitized micrite.

Petrographical analysis of Level 4:

The sediments of Level 4 (L4) exhibit facies indicative of a shallow lagoon domain influenced by tidal cyclicity, periodically affected by high-energy events resulting in the deposition of bioclastic debris layers, typically 1 to 4 meters thick. These layers contain Rudists, suggesting the remobilization of bioclastic material from patch-reefs. Overall, this reservoir unit demonstrates slightly lower quality and porosity values compared to other Cretaceous carbonate reservoirs in Zohr field. It was deposited in environments ranging from tidal flats to lagoons. The lithofacies of L4 comprises interbedded subtidal, intertidal, and supratidal facies. The main facies recognized within L4 include intra-peloidal Wackestone and Packstone with fenestral structures, coated-grain intraclasts-rich Grainstone, bioclastic Packstone with benthic foraminifera, and microbial limestone.

Based on the facies and textures identified from sidewall cores and petrographical analysis, the L4 section is subdivided into several intervals:

- Intra-bioclastic Packstone/Wackestone and skeletal Packstone with benthic foraminifera, calcareous algae, microbial forms, gastropods, and other molluscan fragments. These intervals are associated with subtidal to intertidal flat depositional settings.
- Skeletal Packstone and Wackestone with abundant benthic foraminifera, indicative of a generic subtidal depositional environment.
- Microbial Bindstone with peloids, micro-peloids, intraclasts, small gastropods, and rare benthic foraminifera. These facies are often characterized by desiccation cavities with geopetal infillings, suggesting supratidal to intertidal settings.
- Mud to grain-supported peloidal and skeletal Wackestone and Packstone with fenestral cavities, occasionally interbedded with coated grain Grainstone containing oncoids.
- Peloidal and/or oolitic Grainstone with abundant oncoidal grains. Rudist shells, algae, benthic forams, and small gastropods contribute to the biogenic content.
- Recrystallized/micro-dolomitized bioclastic Mudstone peloidal/Wackestone/Packstone, peloidal-algal Packstone/Grainstone, and mottled/patchy Mudstone (Fig. 8).

Discussion

The findings from petrographical analysis conducted on thin sections and core samples from each of the four reservoir zones (L1, L2, L3, and L4) of the Cretaceous carbonates have been leveraged to establish correlations between wells based on the petrographical characteristics of each reservoir zone. Porosity values obtained from the petrographical analysis, particularly the Point Count Porosity, were utilized to generate a curve. The predominant textures observed in each reservoir zone were employed to refine the correlation process. Identifying reservoir boundaries, which presented significant challenges due to issues such as caving and aging, primarily relied on stratigraphic considerations and formation ages.

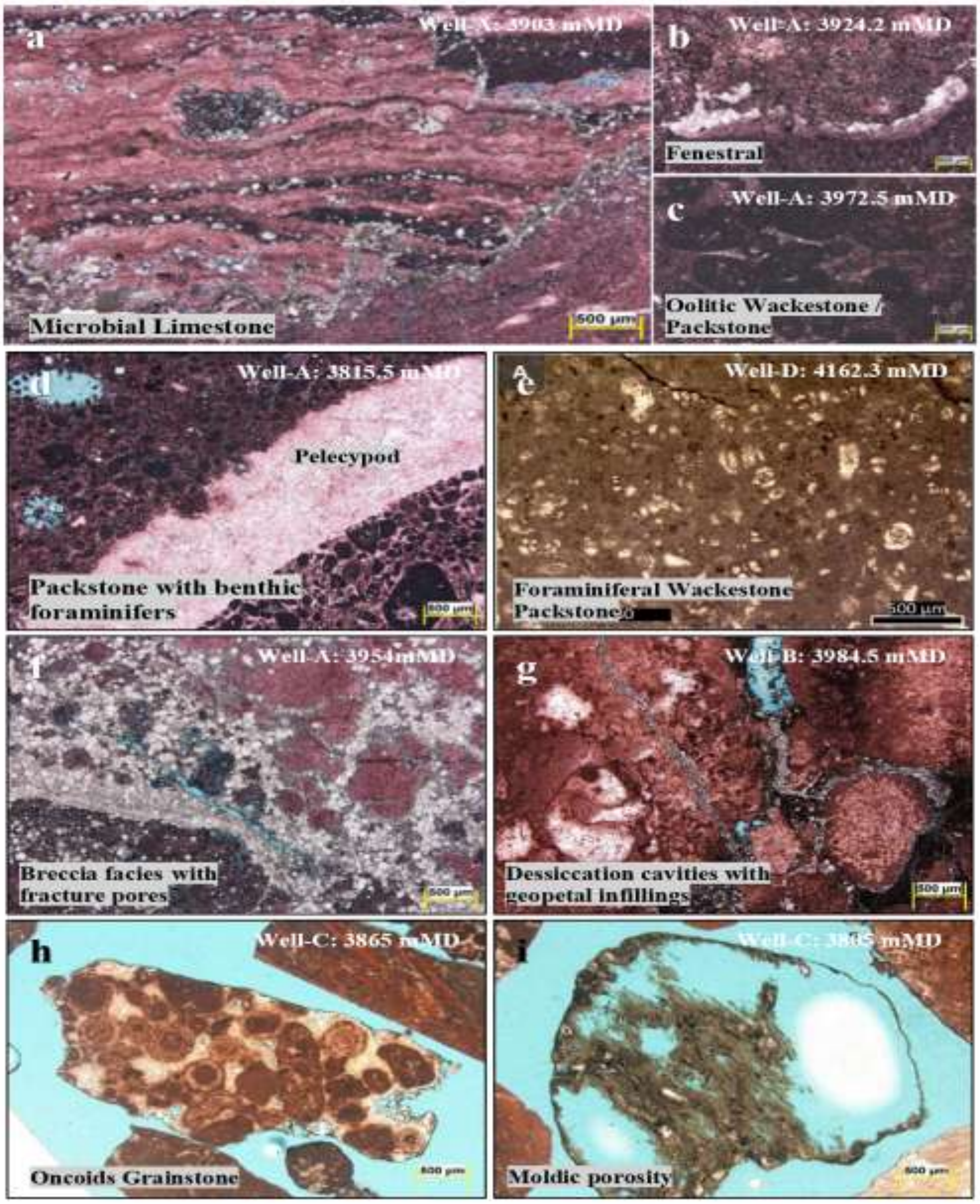

Fig. (8): Photomicrographs of L4 facies, Zohr field. a: Microbial limestone, b: Fenestral, c: Oolitic Wackestone/Packstone, d: Packstone with benthic foraminifers, e: Foraminiferal Wackestone Packstone, f: Breccia facies with fracture pores, g: Dessiccation cavities with geopetal infillings, h: Oncoids Grainstone, i: Mottled/patchy Mudstone.

However, petrographical analysis played a pivotal role in delineating these boundaries more accurately. Microscopic examinations provided detailed insights that facilitated the identification of correlatable features of each zone with greater precision.

Well-A serves as a case study for this approach. It was the first well drilled in the Shorouk Block, targeting Cretaceous carbonate reservoirs. Well-A reached the gas water contact (GWC) at 4080 mMD and the final Total Depth (TD) at 4131 mMD. The reservoir section investigated in Well-A comprises shallow-water, grainy carbonate facies, consisting of interbedded skeletal intra-peloidal Packstones/Wackestones and bioclastic Grainstones/Rudstones with Rudist fragments and Orbitolinids. The paleofaunal assemblage suggests an age range from lower to upper Cretaceous (Aptian to Early Turonian). All four reservoir zones of the Cretaceous carbonate reservoir were encountered in this well and are briefly described as follows :

- **Level 1:** Dominated by diatomaceous marls and calcareous diatomites, micritic limestones, and marls, with an Early Messinian age.
- **Level 2:** The predominant facies observed in this reservoir zone, spanning from the Cenomanian to Early Turonian, are tidal flat/inner lagoon facies. Porosity values for Level 2 facies range from 5% to 30%, depending on biological content and prevailing texture. As illustrated in (Fig. 9), Packstone and Wackestone textures, with a minor contribution from Grainstone, are prevalent. These textures, identified through petrographical analysis of thin sections, are key features of the tidal flat/inner lagoon facies where this specific reservoir zone was deposited. Level 2 mainly comprises oolitic and peloidal grains, with a background texture of Packstone/Wackestone. Porosity values fluctuate, decreasing with depth, and as the boundary with the top Level 3 is approached, the percentage of Grainstone texture increases. The Albian-Cenomanian stratigraphic boundary, a regional unconformity distinguishable on seismic data, corresponds to the boundary between Level 2 and Level 3. Petrographical analysis of thin sections from the lower part of Level 2 and the upper part of Level 3 was conducted to refine this boundary based on dominant texture and changes in the porosity curve. Consequently, the initially estimated seismic boundary at 3598 mMD was adjusted downward by approximately 10 m to 3608 mMD.

This adjustment stemmed from the transition from a mixed facies background texture of Packstone/Wackestone in Level 2 to a Boundstone texture in Level 3, particularly in a patch reef setting. Moreover, the porosity curve exhibited a distinct change from Level 2 to Level 3, prompting the downward adjustment of the L2-L3 boundary to match this porosity variation, as depicted in (Fig. 10). Overall, rocks within Level 2 demonstrate low porosity, characterized by a background texture of Packstone-Wackestone and a significant presence of benthic foraminifera. Porosity values in Level 2 generally range from 5% to 10%, except in areas where Grainstone texture is prevalent.

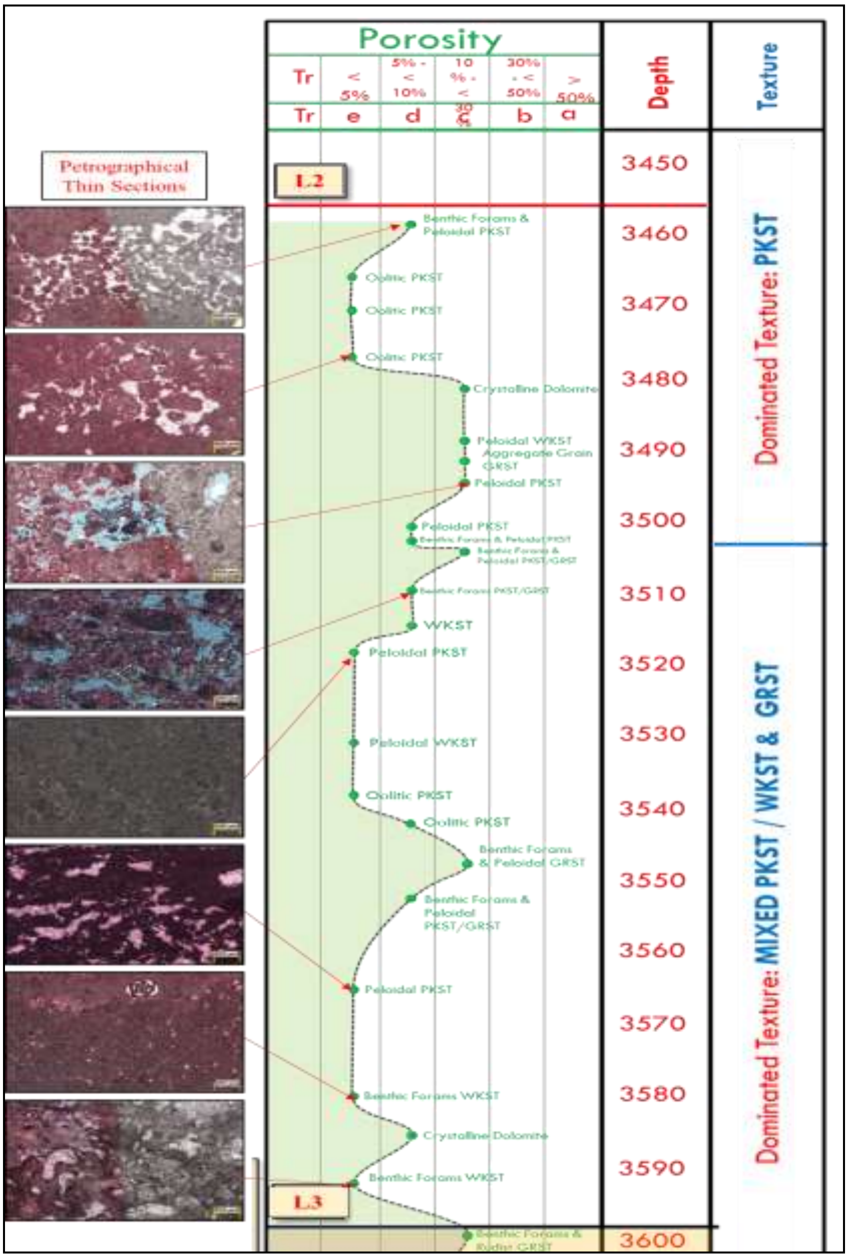

Fig. (9): Porosity and Texture interpretation of Level 2, Well-A

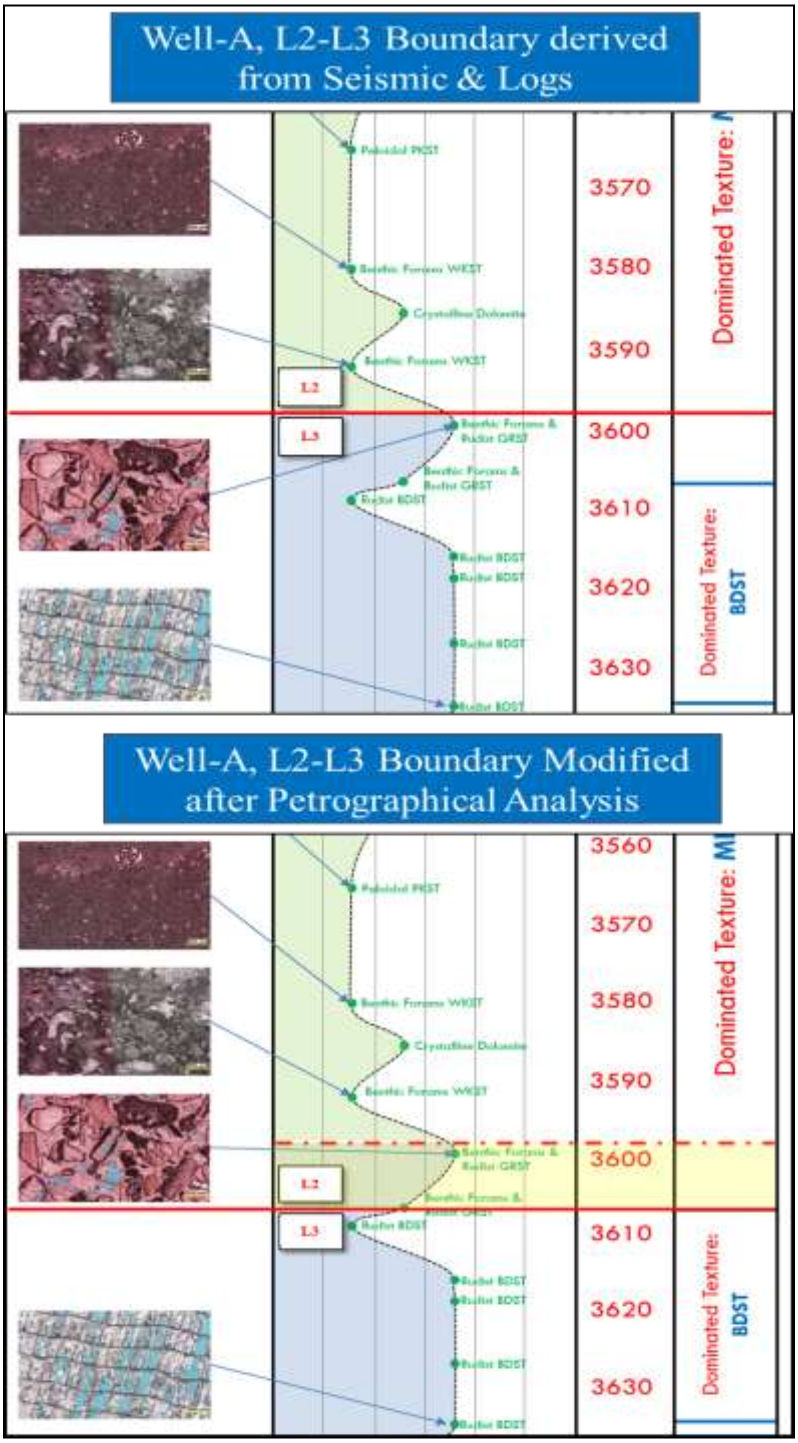

Fig. (10): L2-L3 modified boundary, Well-A

- **Level 3:** Spanning from 3598 to 3807 mMD. This level encompasses facies associated with patch-reefs formed during the Early to Late Albian period. It boasts the highest-quality facies among the Cretaceous Carbonate reservoirs, with porosity levels reaching up to 30%. The predominant background texture in Level 3 consists of Packstone-Grainstone-Boundstone, occasionally interspersed with Dolostone texture, as illustrated in (Fig. 11).

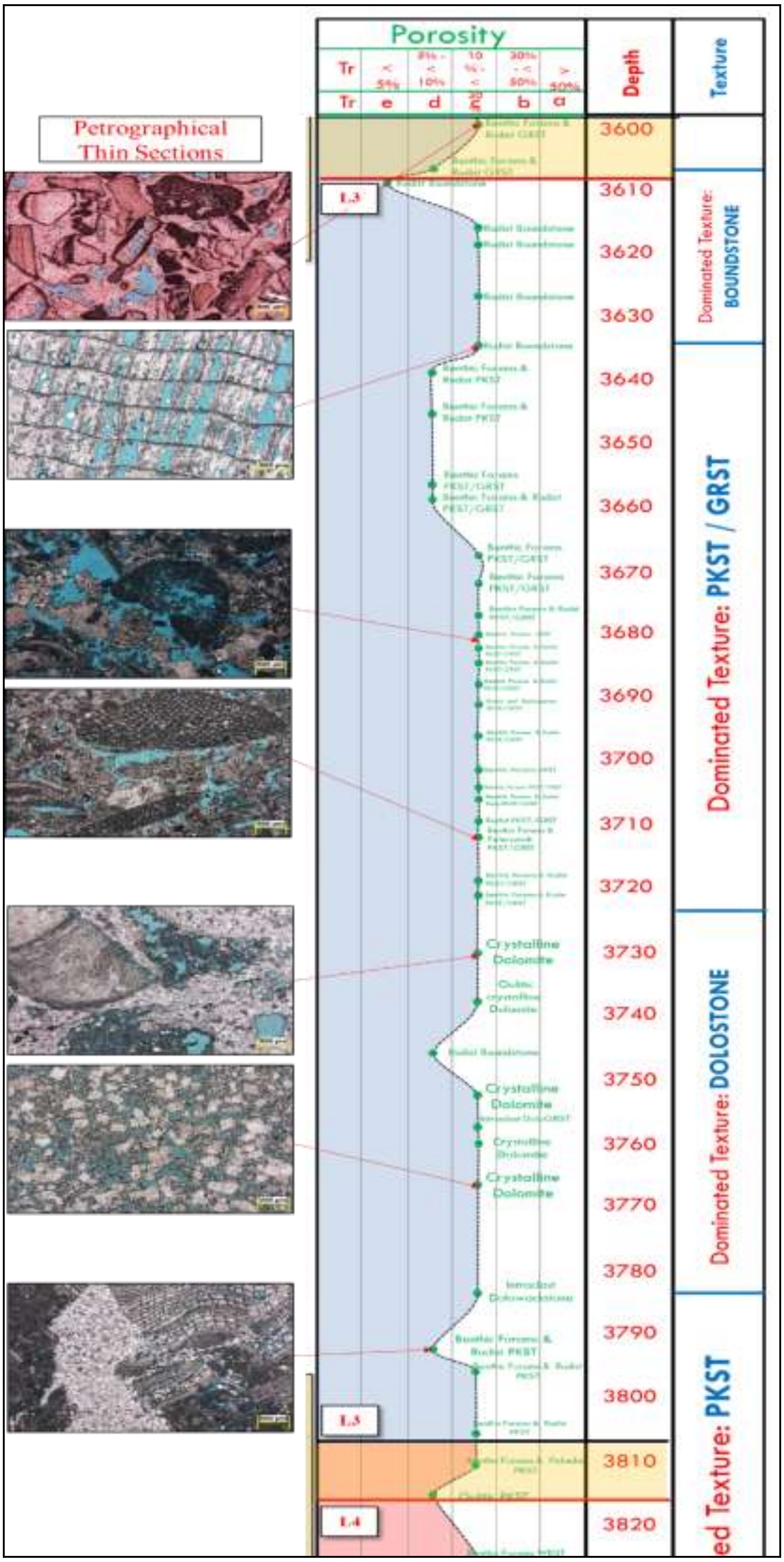

Fig. (11): Porosity and texture interpretation of Level 3, Well-A.

Porosity estimates in this reservoir zone surpass those of other Cretaceous carbonate reservoirs. The combination of high porosity and the prevalence of

Packstone-Grainstone-Boundstone textures is a typical characteristic of depositional settings associated with patch reefs. Rudist formations with moldic porosity significantly contribute to the deposits in Level 3. The boundary between Level 3 and Level 4 closely aligns with the Aptian-Albian stratigraphic boundary, representing another regional unconformity linked to an early Albian deformation phase. Following thin-section analysis, the boundary between Level 3 and Level 4 was adjusted by 10 m (from 3808 to 3818 mMD) to account for observed changes in the porosity curve and variations in background texture, as depicted in (Fig. 12). This adjustment ensures alignment with evident shifts in porosity curve and texture background within the reservoir.

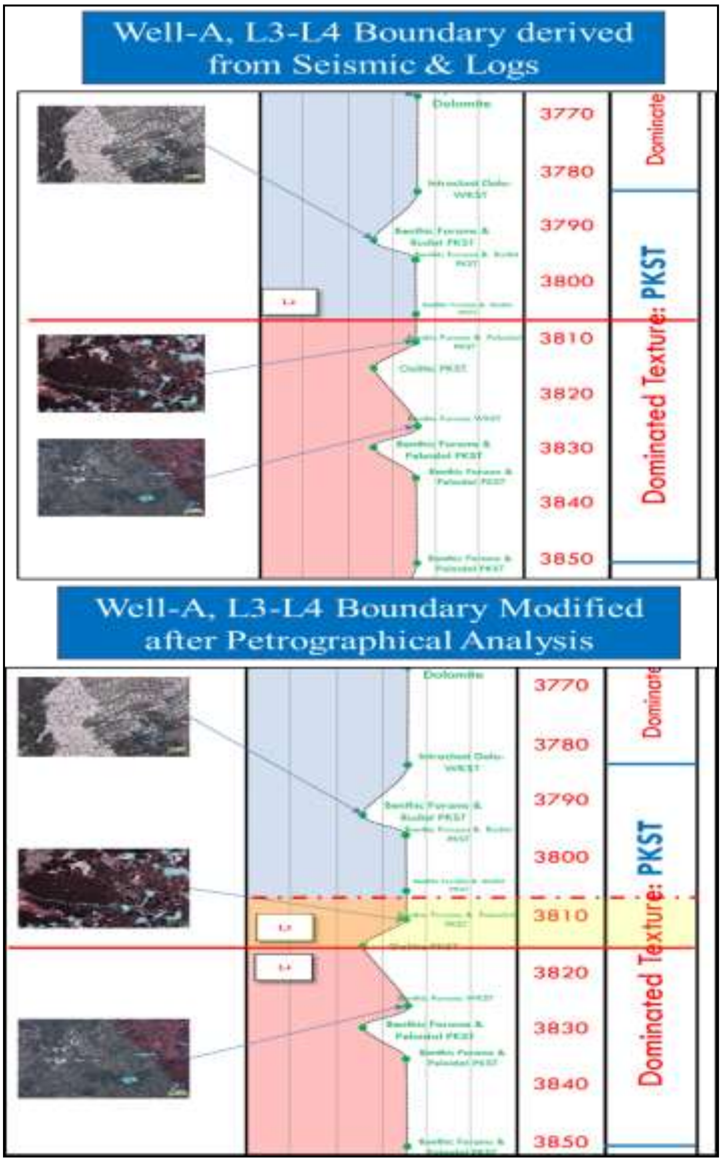

Fig. (12): L3-L4 Modified Boundary, Well-A

- **Level 4:** Ranging from 3807 to 4131 mMD (TD), Level 4 is dominated by tidal flat facies (subtidal, intertidal, supratidal) cyclically organized from the Aptian to Early Albian periods. Porosity estimates for this reservoir zone are moderate and vary widely along studied thin sections (5-20%), with a predominant Wackestone texture background and rare occurrences of Packstone texture, as shown in (Fig. 13). This noticeable variation in porosity and tightness of background texture corresponds with the tidal flat facies recorded along Level 4.

  Common facies include benthic forms with peloidal grains in a Wackestone texture .Through petrographical analysis, boundaries between various Cretaceous carbonate reservoirs in Well-A were identified based on the presence of coarse-grained deposits, particularly breccia facies, corresponding to regional unconformities. At the L2-L3 and L3-L4 boundaries, breccia facies characterized by a coarse-grained texture with Wackestone/Packstone composition were observed. Interestingly, these breccia facies were not initially recognized through logs and seismic investigations, as depicted in (Fig. 14). Consequently, the boundaries between these reservoir zones should be defined as zones rather than specific depths to ensure accuracy and prevent correlation issues, as illustrated in (Fig. 15).

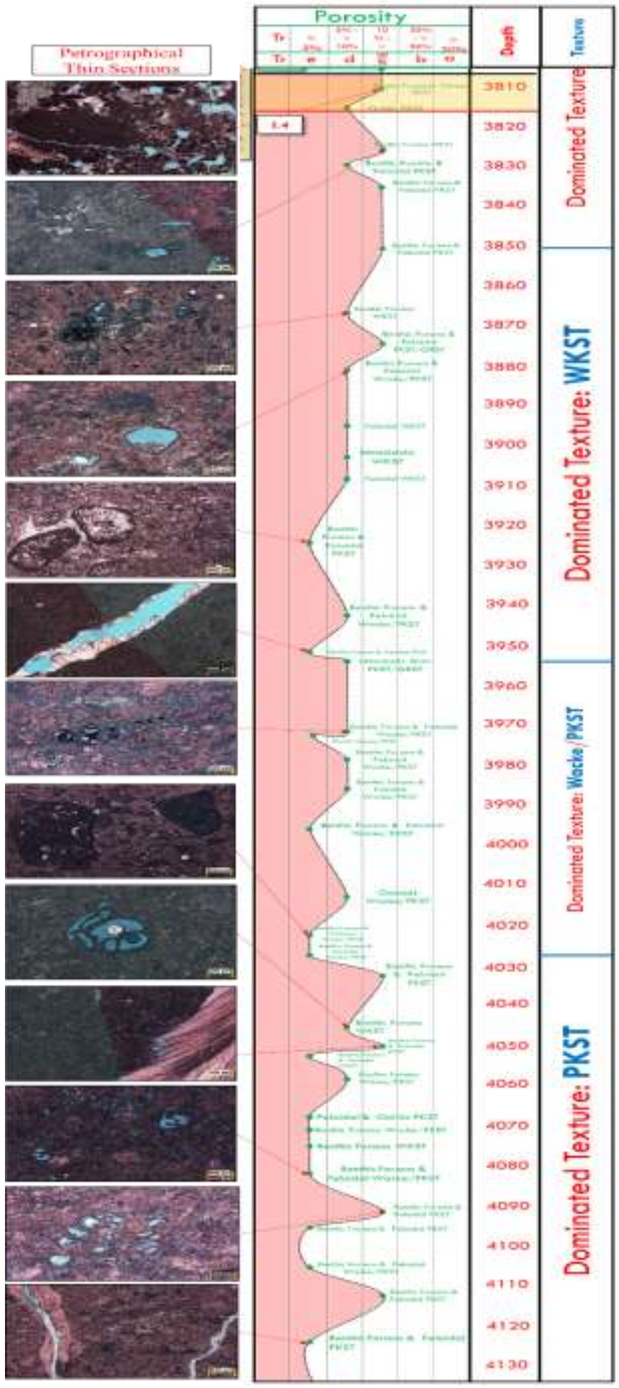

Fig. (13): Porosity and texture interpretation of Level 4, Well-A.

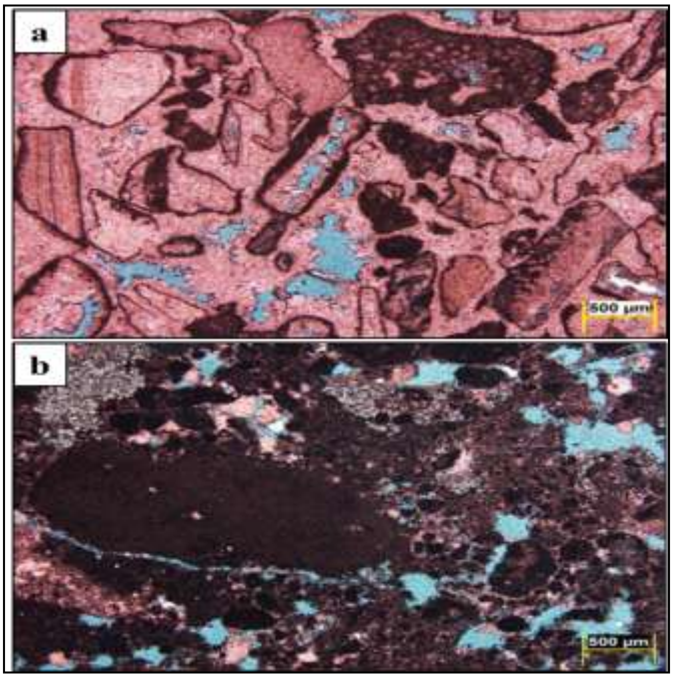

Fig. (14): Photomicrographs showing breccia Facies along reservoir boundary. a: L2-L3 boundary facies. b: L3-L4 boundary facies, Well-A

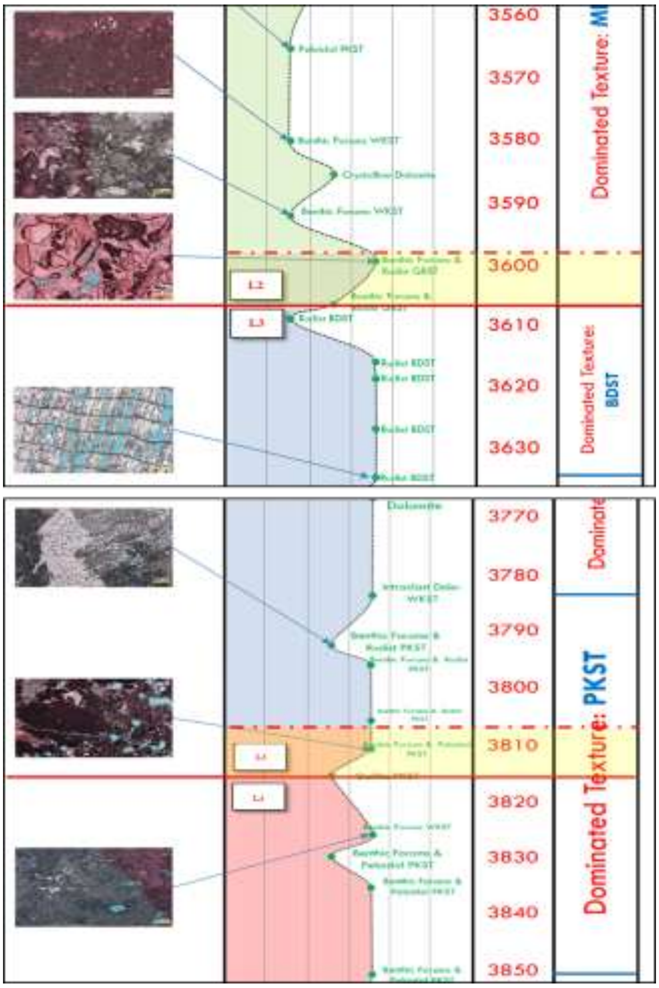

Fig. (15): Well-A, Petrographical Analysis

Conclusion

The present analysis offers a valuable insight into the adjustments made to the reservoir boundaries within the Cretaceous reservoirs of the Zohr field, along with highlighting the general characteristics of these reservoirs from a petrographical perspective. The petrographical analysis encompassed the examination of over 100 samples from all Cretaceous-aged reservoirs in the Zohr field. The interpretation of these samples relied on both the biostratigraphic content for age determination and the identification of facies to comprehend the depositional environment of each reservoir. The results derived from this meticulous petrographical analysis were translated into porosity and texture curves, revealing subtle characteristics of the Cretaceous Reservoirs that eluded detection through well logs and seismic data alone. These curves played a pivotal role in refining and fine-tuning the boundaries of the Cretaceous Reservoirs, initially determined through seismic interpretation, well log correlation, and reservoir age. As a recommendation, the utilization of sedimentological approaches, particularly petrographical analysis, proves to be beneficial and more accurate in describing and delineating the boundaries and internal characteristics of different reservoirs. This approach integrates age information derived from biostratigraphic studies, which is further adjusted through petrographical analysis to accommodate phenomena such as caving in carbonate rocks. It holds particular value in the context of carbonate rock formations due to their inherent heterogeneity and the discontinuity of their characteristics, both vertically and laterally.

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Data Availability

All data generated or analyzed during this study are included in this published article.

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تقسيم خزان الكربونات من العصر الطباشيري في شرق البحر المتوسط، مصر، بناءً على الخصائص البتروغرافية: دراسة حالة

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تتطلب دراسات الخزانات الكربونية تصنيفاً متسقاً وقابلاً للتكرار، وهو يعتبر مدخلاً أساسياً لبناء النماذج الترسيبية ونماذج الخزان فى حقل ظهر (منطقة الدراسة) والذى يقع على بُعد ١٥٠ كم في المياه العميقة قبالة السواحل المصرية بشرق البحر الأبيض المتوسط، داخل الحدود الاقتصادية المصرية الخالصة ويغطي حوالي ١٠٠ كيلومتراً مربعاً ضمن مساحة إجمالية ٣٧٥٢ كيلومتراً مربعا، وهي تمثل منطقة إمتياز الشروق البحري. تم تقسيم الخزان الكربونى من العصر الطباشيري في حقل ظهر إلى أربعة مستويات على أساس التحليل الطبقي الحيوي (الإستراتيجرافى) حيث وجد أن الجزء العلوي من الخزان الجيرى يتوافق مع قاعدة طبقات المتبخرات العلوية من العصر الميسينى. أولى هذه الطبقات من الأعلى تسمى المستوى الأول حيث يتراوح عمرها من العصر الطباشيرى العلوى إلى العصر الثلاثى، وتحتوي على مخلفات عوالق وفيرة وتليها فى الإتجاه السفلى طبقات المستوىات الثانى، الثالث و الرابع الذين يمثلون خزانات الغاز الرئيسين فى منصة العصر الطباشيرى الكربونية . تُظهر هذه المستويات إختلافات في السمك والسحنات الترسيبية وكذا فى الخواص البتروفيزيائية، مما يؤدي في كثير من الأحيان إلى اختلافات بين الآبار حيث يكون من الصعب ربط التسجيلات الكهربائية بين تلك الآبار. يرجع ذلك إلى التباينات الجانبية في السحنات الترسيبية والتغيرات الترسيبية المرافقة إضافة للتغيرات بعد الترسيب. تهدف هذه الدراسة إلى دراسة سحنات الصخور الكربونية ذات العمر الطباشيرى في حقل ظهر من خلال استخدام نهج التحليل الصخري المفصل والشامل الذي يسمح بتصنيف أكثر دقة لهذه الصخور مقارنة بالأساليب التقليدية. تم دراسة مجموعة متنوعة من الأنسجة الصخرية والتراكيب الصخرية الطبيعية إضافة إلى المقاطع الرقيقة المشتقة من العينات الصخرية الإسطوانية والفتاتية. نتيجة لذلك، ساهمت نتائج هذا التحليل الصخرى في تحسين حدود الخزان الحالية. تم إعتماد الحدود المعدلة المستمدة من التحليل الصخرى ، مما يسهل تطوير نماذج ترسيبية وتشريحية ونماذج خزان أكثر واقعية. علاوةً على ذلك، تم استخدام النتائج لإنشاء منحنيات الأنسجة والمسامية، مما يتيح الترابط التفصيلي والدقيق بين الآبار المختلفة والمستويات الخزانية في حقل ظهر.