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# Palynofacies analysis and palaeoenvironmental interpretation of the upper cretaceous sediments, Shushan Basin, northern western desert, Egypt

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**Abstract:** The purpose of this research is to investigate the palynofacies analysis and palynomorph assemblages of the Salam-53 well, Shushan Basin, north-western Desert, Egypt to show the shelf conditions throughout the Upper Cretaceous deposits, where two palynofacies types have been documented based on the properties components of palynofacies of the studied ditch cutting samples. PF-1, the upper Bahariya clastic-carbonate layer, and the Abu Roash "G" as well as "F" to "C" members were discovered in the inner shelf setting, marine transgression occurs at the late Cenomanian-Turonian dominated by reducing (suboxic-anoxic) settings with occasional local oxic-dysoxic conditions. The global late Cenomanian marine transgression was primarily responsible for this relative sea level rise. PF-2 represents the remainder of the carbonate section ("B" and "A" members) of the Abu Roash and Khoman formations, which were deposited in middle shelf environments with prominent suboxic-anoxic conditions during a major regional marine transgression, which was primarily associated with the global Turonian-Maastrichtian eustatic sea-level rise. Furthermore, palynofacies analyses were used to reconstruct the vegetation cover and palaeoclimatic conditions at these times, indicating that regional warm and relatively dry climatic conditions prevailed. This based on the presence of *Afropollis jardinus*, *Classopollis* spp., *Ephedripites* spp., *Elaterspores*, and *pteridophytes*, indicating a paleoenvironment in which parent plants inhabiting wetlands in a humid condition, developed near the well site.

**Keywords**: Palynofacies – paleoenvironment – paleoclimate – Cretaceous – Shushan Basin – Egypt.

## 1 Introduction

Deposits from the Upper Cretaceous of north-western desert of Egypt are notable due to the presence of several source-reservoir rocks, particularly the Abu Roash "G" Member of the Shushan Basin, which show very good to exceptional potential source rock [**1**]. The Shushan Basin includes clastic reservoirs and is considered one of Egypt's most important petroliferous Mesozoic basins, has lately been identified as one of the most promising but difficult exploration opportunities in the northwestern desert [**2**]. This is due to the complicated structural history (Fig. 1), and investigation has been almost entirely focused on structural traps [**3**].

As a result, national and international exploration companies are presently conducting a large-scale regional correlation inside the Shushan Basin to differentiate the almost identical conventional clastic reservoirs. In recent years, palynofacies investigations have been established and disseminated as a valuable tool for interpreting paleoenvironmental conditions and related organic geochemical conclusions e.g. [**4**, **5**, **6**, **7**]. Some aspects must be considered when interpreting the spatial palynofacies pattern in terms of paleoenvironment and analyzing stratigraphic palynofacies fluctuations in terms of sea level changes.

The current study depicted the stratigraphic distribution of palynomorphs and particulate organic matter in order to interpret the palynofacies and paleoenvironments of the Upper Cretaceous successions penetrated by the salam-53 well, Northwestern Desert, Egypt, as well as to display the conditions of palaeoclimatic and recreate palaeovegetation coverings, which developed adjacent/at the studied region.

## Geological setting and stratigraphy

The Upper Cretaceous period in Egypt is distinguished by the start of a significant marine transgression that resulted by a carbonate-dominated section, which was

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deposited in the studied region. The study area (Salam Field) is located in the Shushan basin (Fig. 1 a), which inverted during the late Cretaceous period following the Syrian arc phase [**8**], where the Shushan basin is located within the tectonic zone of the unstable shelf, which was tectonically active for the majority of the Paleozoic to Early Cenozoic period [**9**]. According [**10**], the Shushan Basin is a half-graben system that formed during the Late Jurassic-Early Cretaceous as a NE-SW extensional basin receiving only continental and fluvio-lacustrine sediments and was later converted into a pull-apart basin during the Late Cretaceous as a result of the rifting and separation of the North African plate from the European plate [**2**]. The Salam-53 borehole investigated succession represents the top Cretaceous in the northern Western Desert. As seen from top to bottom, the sequence consists of Khoman, Abu Roash, and Bahariya are belonging to Cenomanian to Campanian-Maastrichtian in age. The lithological descriptions are given in (Fig. 1 b). The formations are detailed below in order of age:

### 1. Bahariya Formation

[**9**] established this unit and [**11**] identified it as a formational name from the Bahariya-1 well, which extends in the subsurface throughout much of the Western Desert and rests conformably to unconformably on the Kharita Formation and is conformably overlain by the Abu Roash Formation. Its surface type section is 567 feet (173 metres) thick and is found in the Bahariya Oasis of the Western Desert at Gebel El Dist [**10**]. The Bahariya Formation is made up of sandstones that alternate with variegated shales and topped by limestones. Foraminifera [**12, 13**] and palynological evidence show mid-late Albian to early Cenomanian ages [**14**, **15**], early Cenomanian [**16**], [**17**], and/or early middle Cenomanian ages [**18, 4, 19, 20, 21, 22, 23**]. This formation was thought to have formed in shallow marine to fluviomarine–deltaic environments [**24**, **25, 26**]. Furthermore, palynological studies on this formation reflect the aforementioned depositional settings [**18, 27, 19, 23**]. In this borehole it reaches a height of 170 ft (52 m) and is found in depths ranging from 5870 to 6040 ft in the studied well.

### 2. Abu Roash Formation

The first to describe this Formation was [**28**], while [**11**] was the second. Its type of section is 217 m (712 ft) thick at the Abu Roash-1 well in the northern Western Desert [**10**]. Lithostratigraphiclly, this formation is made up of seven members, symbolized by top to bottom as A, B, C, D, E, F, and G, and extends in age from the Turonian to the Upper Cenomanian [**12**]. This formation is primarily chalky limestone with shale and sandstone horizons interbedded. This Formation is overlain conformable by the Khoman Formation and underlain conformable by the Bahariya Formation, and its age spans from foraminifera-based Turonian-early Santonian [**13**] to Late Cenomanian-Coniacian/Santonian [**12**]. The Abu Roash Formation is palynologically dated as early Cenomanian-Santonian [**18**] and late Cenomanian-Turonian [**18, 23, 6**]. Except for the "G" Member, which was produced in lagoonal to medium shelf conditions, the facies of this formation were mostly deposited in neritic to open marine, basinal conditions [**10**]. Apart from unit G, which is thought to be of lagoonal origin in the south, this formation was thought to have been deposited in an open shallow maritime shelf context [**10**]. In this well, it reaches a height of 625 m (2050 ft) and is found in depths ranging from 1158 to 1783 m. (3800-5850 ft).

### 3. Khoman Formation

It was illustrated by [**29**] and classified as a formation by [**11**]. The type section is located southwest of the Bahariya Oasis in Ain Khoman. This formation consists of two units: the Khoman "B" that considered as a base unit and composed of limestone intercalations with shale, and the Khoman "A", which known as the upper unit and composed of dolomite and fine-grained white chalky limestone [**25**]. It unconformably overlies the Abu-Roash Formation, notably in the structurally highest section, and unconformably underlyies the Apollonia or Dabaa formations [**10**]. The top unit Khoman "A" is dated from the late Santonian to the Campanian-Maastrichtian period, while the lower unit Khoman "B" is dated from the Coniacian to the early Santonian period [**10**]. It is thought to have been deposited in open marine environments ranging from the shelf to deeper upper to middle slope settings [**30**]. In the studied well, it reaches a height of 258 m (850 ft) and is found in depths ranging from 879 to 1137 m. (2880-3730 ft).

## 2 Material and Methods

Twenty-eight ditch-cutting samples were collected from the Salam-53 well's upper Bahariya, Abu Roash, and Khoman formations, northern Western Desert, Egypt (30° 42′ 18.7364 ″ N and 26° 58′ 21.0916 ″ E) and treated using traditional palynological techniques (HCl (10%), HF (40%) treatment steps, and staining) to digest and remove the carbonates and silicates respectively [**31**].

The samples examined range in depth from 2660 ft to 6040 ft (811-1841 m). Approximately 20 grams of each sample were subjected to conventional palynological procedures. To preserve the organic materials for the palynofacies analysis, neither oxidation nor ultrasonic treatments were used. After that, the residue was sieved using a 10m nylon sieve. Three to five slides were made from the residue of each rock sample and analysed for light microscopy and photomicrography by using a mounting medium as glycerin jelly. A count of around 150 palynomorph grains was performed to establish a good record of palynomorphs from each sample because of the very limited samples and their poverty in fossil content to counter the dilution effect of AOM [**32**]. Each sample was subjected to a second separate count of 200 phytoclasts and AOM particles in order to calculate relative abundances: most of the samples were poorly fossiliferous. The amounts reported were divided into four categories: extremely abundant > 50%, plentiful 36–50%, frequent 16–35%, common 5–15%, and uncommon 5%. The study of palynofacies is based on the percentage frequency of various palynological organic matter (POM) components classified by [**32**]. For a detailed palaeoenvironmental study based on palynofacies parameters (SOM) were counted to calculate relative abundances in percentages (Fig.2) derivative from two distinct subsets as a palynomorphs group and a kerogen group (brown phytoclasts, black phytoclasts, and AOM) as noted by [**32**]. In addition to providing some quantitative values for paleoecological interpretation.

[**32**] classified the percentage frequency of diverse palynological organic matter (POM) components that used to study palynofacies.

In this study, both residues and slides utilised were kept at the Geology Department's Geological Museum at Sohag University's Faculty of Science, Egypt. Axiolab Zeiss transmission light microscopy was used to analyze the slides, and microphotographing was done using its own digital camera.

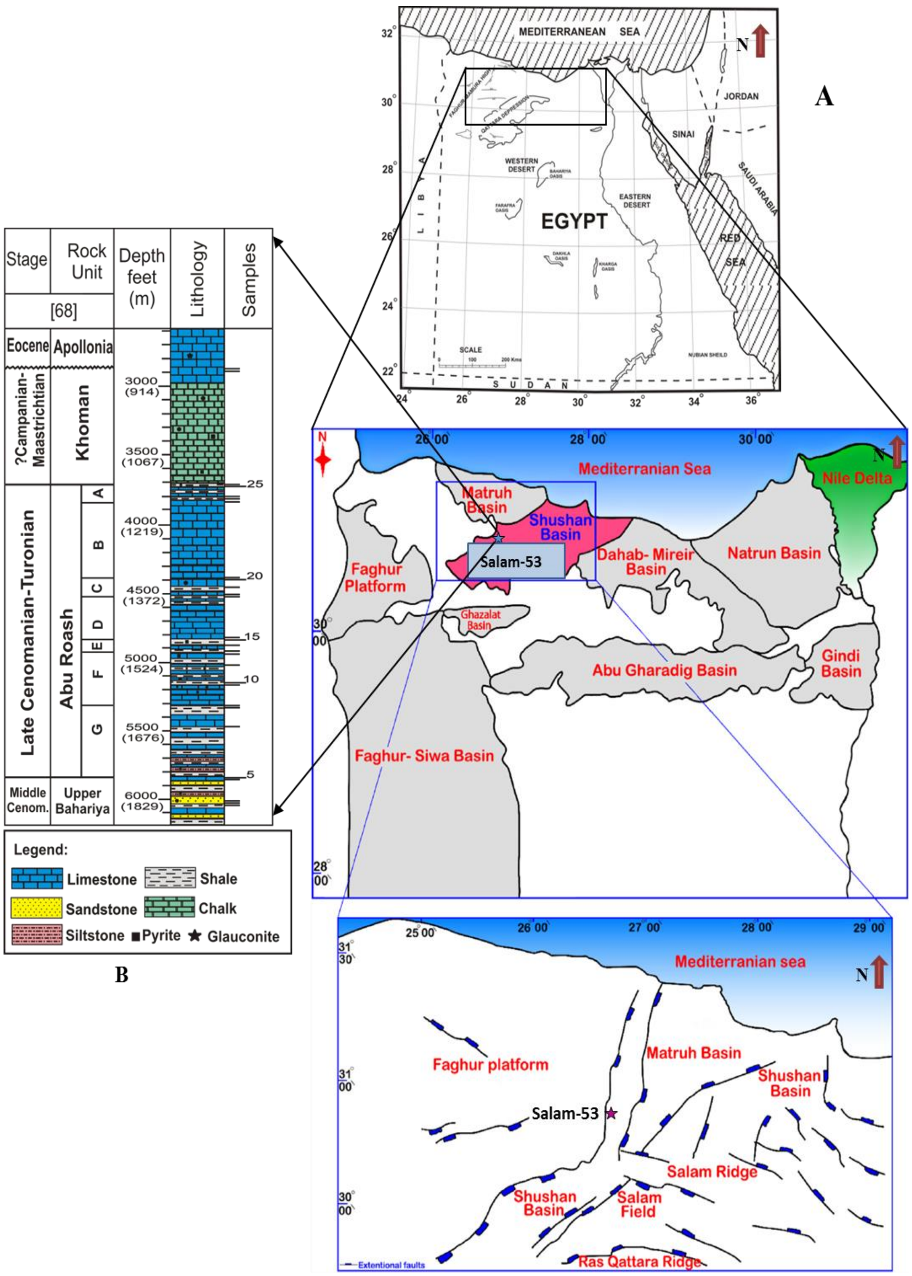


**Fig. 1**: A-The location map of the salam-53 well under study, northwestern Desert, Egypt viewing the main Mesozoic basins, and the main fault systems. After [67], B- Stratigraphic column of the Salam-53 borehole showing the lithological characteristics.

## 3 Results and discussion

### palynofacies analysis and paleoenvironmental interpretation

The analysis of palynofacies is regarded as an insightful tool for paleoenvironmental interpretation in terms of content of oxygen, proximity to sediment source or landmass, and sea level changes [32, 33], based on relative variations in the composition, type, nature, and proportions of the palynomorph assemblages with their quantity, which were combined to reveal the direct response to the influence of the paleoenvironmental conditions that are extant. Furthermore, the palynofacies study may be combined with their facies of lithology besides the additional minerals (e.g., glauconite and pyrite) to aid in the addition of significant information in this trend e.g. [23, 34, 35, 36].

According to [32] the forms of particulate organic matter detected here are palynomorphs, phytoclasts (brown wood and cuticles), opaque phytoclasts (oxidized or carbonized brownish black to black woody tissues), and amorphous organic matter (AOM). As a result, the palynofacies data have been spatially and stratigraphically synthesized in order to investigate differences in the distribution of palynomorphs and particulate organic matter with regard to both paleoenvironment and relative sea level changes (Fig. 2). The Tyson ternary diagram can provide valuable information about the environmental conditions that prevailed during deposition (Fig. 3). The palynomorphs group is deficient in most of the Salam-53 examined samples, which gave fair diversity and fair to moderately preserved terrestrial palynomorphs generated from plant debries and dinocystes, which exhibited extremely low diversity and abundance fewer than miospores (plate, 1). The studied samples show that palynomorphs are extensively diluted with AOM, which can reach up to 70% of the total POM. Phytoclasts, on the other hand, are frequent components in the majority of the samples and exhibit modest preservation compared to palynomorphs (plate, 1). The frequency distribution of various POM is frequently found to be adequate for the current palynofacies investigation [6]. This well may be split into two palynofacies types based on the percentage changes in each particle organic matter category, as shown below:

### 3.1 Palynofacies (PF-1): inner shelf

This palynofacies was discovered in the upper Bahariya Formation and encompasses the lower part of the Abu Roash Formation "G" through "C" members; it is considered the oldest and covers samples (1-20) at depths of 6040–4400 ft /1841–1341 m. It is defined by a very high content (very abundant) of amorphous organic matter (AOM) (avg. 64%), frequent phytoclasts (avg. 35%), extremely numerous sporomorphs (avg. 83%), uncommon dinoflagellate cysts (avg. 4%), and common MFTLs (avg. 15%) occurrences (Fig. 2). This palynofacies' uncommon dinoflagellate cyst abundances and low species richness (avg. 4%) imply a stressed marginal marine habitat with below-normal salinity e.g. [37, 38]. The assemblage of dinoflagellate cysts in this palynofacies displays rare occurrences (avg. 3 percent) of open marine (middle shelf) *Florentinia*, chorate cysts [38, 39, 40]. Furthermore, the only additional middle shelf chorate cysts (avg. 5%) of *Spiniferites* sp are found in the bottom half of PF-1 in Sample 1. Despite the absence of components from the inner shelf paleoenvironment, the presence of cavate and adjacent cysts supports this context. The presence of chorate cysts at low concentrations might be owing to a fluctuation of infrequent maritime invasions that may have reached the site of PF-1 deposition at some point, or to transportation of these chorate cysts by marine currents and redeposition in more nearshore environments.

The unusual quantity and low variety (just two species) of dinoflagellate cysts and frequent MFTLs hint to confined marginal to inner shelf marine habitats, as dinocyst species diversity is substantially lower in water with lower salinity [37, 41]. As a result, the uncommon quantity of dinoflagellates cysts confirms the deeper state. These shallower circumstances are further supported by the widespread presence of MFTLs, which are known to decline in the quantity of marginal marine species environments and rise in abundance in normal marine settings [38, 42]. The increase in MFTLs at the end of this PF-1 indicates that a modest maritime transgression caused by a local sea level rise occurred during the deposition of this portion of PF-1, e.g. [38, 42]. The dominance of continental (avg. 83%) over marine (avg. 15%) palynomorphs suggests the depositional site's closeness to the inner shelf setting, e.g. [33, 43]. As a result, the deposition occurred swiftly in a quiet state relatively near to the coast and source vegetation. The dominance of pteridophyte spores (avg. 47.5 percent) over sphaeroidal gymnosperm pollen grains (*Araucariacites*, *Cycadopites* spp, *Exesipollenites*) in the sporomorph assemblage implies PF-1 deposition in shallow marginal marine environments, most likely on the inner shelf. This is based on the spore-parent plants' ecological preferences and reproduction rates, since they flourish in these locations and are known to be less prolific than gymnosperm pollen-producing plants (Fig. 2). Furthermore, pteridophyte spores have lower transport efficiency than sphaeroidal pollen grains, which are more buoyant and easily carried, e.g. [31, 32].

The gymnosperm pollens are dominated by *araucariacites*, which are produced by conifers in the comparably dry hinterland and are linked with *Epheidroids* and *Classopollis*. Furthermore, the frequent abundances (avg. 15%) of *Araucariacites* large sphaeroidal pollen grains (63–72 m) in the lower PF-1 silty sandstone and siltstone, as well as their moderate upward reduction (Fig. 2), indicate a slight depth in the depositional environment. This is predicated on the interaction between sea-level changes and the flow regime's sorting influence on sporomorphs [32].

[44] and [45] discovered that sporomorphs with

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lengths higher than 50 m are abundant in fine sands, but in finer siltsone lithology, the smaller sporomorphs were found. In the similar circumstance, the increasing upward of *Classopollis* pollen grains (31–35 m) at the upper PF-1 shale and siltstone confirms the little sea invasion, since [44] revealed that the increasing distally of this pollen grains in siltstones and other finer layers. Furthermore, the significant AOM accumulations in shale and limestone (Fig. 2), as well as the widespread abundance of MFTLs, refer to a proximal reducing (suboxic-anoxic) environment that was slightly isolated from substantial terrestrial inputs and has a low rate of sedimentation [46, 32]. These decreasing (suboxic-anoxic) circumstances are further supported by [32] APP ternary diagram and [47] TPOM ternary diagram (Fig. 2, 3 A and B, Tab. 1).

The abundance of palynodebris (Fig. 2) implies considerable terrestrial input and deposition in marginal marine settings near land vegetation [32]. The general memorable occurrence of terrestrial influx represented by very abundant sporomorphs and frequent phytoclasts indicates deposition in proximal setting [32, 48], with particular emphasis on the frequent abundance of Afropollis (avg. 5.5%) and Elaterosporites (avg. 5%) pollen grains.

Local oxic-dysoxic conditions (Fig. 3 A and B, Tab. 1) may have disrupted the dominant decreasing (suboxic-anoxic) conditions, as demonstrated by the uncommon emergence of fungus spores (avg. 28 percent) e.g. [32, 49]. The growing trend of black wood portions in the upper PF-1 corroborats the distal inner shelf environment in that region of the palynofacies. The transition from siltstones and sandstones to shale and carbonate as well suggests a shallow depth of depositional settings [50, 51, 36]. The mineral glauconite is known to exist in marine waters at the sediment-water interface and is associated with a very low sedimentation rate and non-deposition e.g. [52], hence it exists in a rare concentration with free traces of pyrite. The palynological and lithologic criteria indicate a slight movement from the proximal to distal inner shelf environment in the depositional setting, and it is possible that the section of mixed clastic-carbonate (samples 1–6) for the top of Bahariya and the lowermost section of the "G" Member of Abu Roash formations were deposited in a brackish proximal inner shelf environment that had significant variations in regional sea level.

The reducing conditions (suboxic-anoxic) prevailed, however was briefly disrupted by local conditions (anoxic-dysoxic). A slight marine transgression, predominantly for the rising of the global sea level, occurred in the deposition of the upper members of "G" and "F" to "C" (samples 7–20) at a distant portion of the inner shelf habitat under the same conditions of reducing (suboxic-anoxic). Furthermore, the upward progressive sedimentation of the higher PF-1 unit, which is mostly limestone, with no breaks in sedimentation implies that the local tectonics did not reason for the proportional rise in sea level. The global late Cenomanian marine transgression was principally responsible for this elevation that at the time comprised the majority of northern Egypt [8, 25, 53, 54].

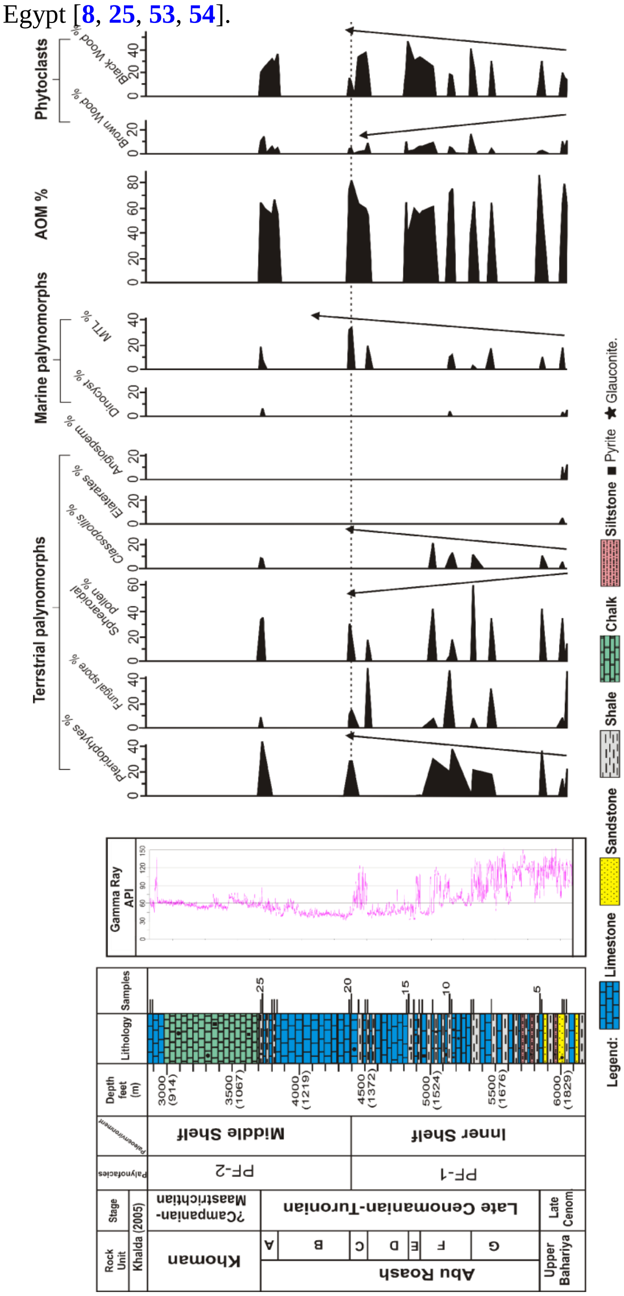


**Fig. 2:** Percentage abundances of some certain particulate organic matter and palynomorphs of the Salam-53 well, northern Western Desert, Egypt.

## 3.2 Palynofacies (PF-2): middle shelf

This thecond palynofacies occurs directly above PF-1 and has been seen to synchronize in the Abu Roash and Khoman formations' "B" and "A" members (samples 21–28 at depth (4390–2880 ft /1338–878 m).

This palynofacies is characterized by high abundances (avg. 67 %) of AOM, frequent phytoclasts (avg. 29 %), and extremely numerous sporomorphs (avg. 83 percent), whereas marine dinoflagellate cysts have uncommon abundances (avg. 3 %) and frequent (avg. 16 %) MTLs.

This palynofacies appears to be comparable to those found in pf-1 in the assemblage of dinoflagellate cysts, with similar species diversity. However, it differs from it in the containment of a single grain of restricted-inner shelf *Subtilisphaera* cysts in sample 1 [**38**, **55**], where the middle shelf cysts of *Spiniferites* sp. occur in the open marine (Fig. 2), but it has a higher concentration in the middle shelf cysts (avg. 2.5 %) than the restricted-inner shelf *Subtilisphaera* cysts (avg. 0.5 %).

As a result, the deeper condition of middle shelf occurs. Under normal marine circumstances, the relative abundances of microforaminiferal test linings can be utilized to infer depositional settings [**38**].

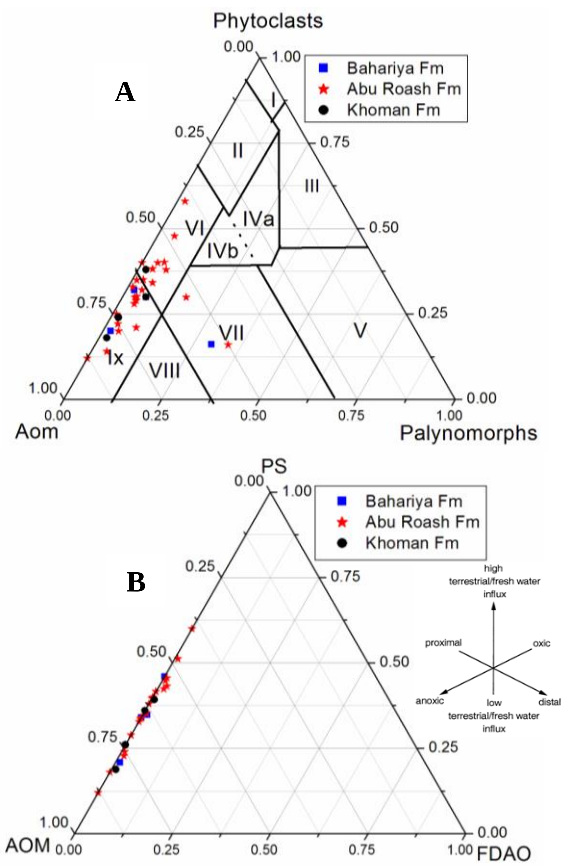


**Fig. (3):** A. The ternary APP diagram of Salam-53 borehole palynofacies plot [**32**], B. The Salam-53 borehole percentage frequency of total sedimentary organic matter (% TPOM) [**46**].

This might be referring to the formation of a somewhat shelfal setting deeper. Furthermore, the virtual MFTLs abundance along with inconsiderable declines in organic matter terrestrial (i.e., brown phytoclasts) supports a deeper shelf environment than that previously presumed for PF-1, most likely a proximal middle shelf setting.

Also, the sphaeroidal pollen grain concentration (avg. 45%) surpasses the pteridophytes (avg. 39%) in this palynofacies compared to the pf-1, indicating a deeper condition (middle shelf), where the Sphaeroidal pollen define the basinward direction due to their high buoyancy [**33**].

The high proportion of AOM (avg. 67%) in this palynofacies compared to Pf-1 (avg. 64%), where the increasing concentration of AOM signals deeper circumstances while AOM has been observed tends to be decrease in shallow shelf sediments and increases in a basinward direction with dysoxic-anoxic conditions, e.g. [**56**, **57**]. The high abundance of AOM indicates periodic deposition in somewhat further out settings away from non-marine sources when dysoxic-oxic conditions predominate [**32**, **33**]. Furthermore, the ternary kerogen diagrams produced by [**32**] and [**47**] (Fig. 3 A and B, Tab. 1), together with a larger abundance of AOM that was largely affected by weak terrigenous influxes [**32**, **33**], indicate the shallower circumstances (middle shelf).

Khoman's chalky formation of this palynofacies has a dispersed sample; therefore, this may be poor evidence in the interpretation of this environment of palynofacies. The lithologies of these formations, which correspond to this palynofacies, where chalk and chalky limestone deposits defined the shallow and deep shelfal settings, provide additional evidence for this hypothesis, e.g. [**46**, **58**]. Furthermore, the upward warding sequence of thick limestone without any missing parts and a significant sequence of fining upward that denoted by the unit of chalk confirms shallow to deep shelfal settings. Collecting all of this information, either sedimentological and palynological analysis proposed that the "B" besides "A" members of Abu Roash and the Khoman formations were found in the open marine, inner and outer middle shelf setting, respectively, under prevailing conditions of reducing (suboxic-anoxic) and refers to the increasing upward in Shushan Basin water depth, which was unrelated to local tectonics but to the major global Turonian-Maastrichtian marine transgression [**8, 25, 53, 54**].

## Palaeovegetation cover and palaeoclimate implications

The spread of any fossil assemblage that correlates with a change in lithology in any stratigraphic section may be limited by palaeoecological variables or evolution [**59**]. The presence of terrestrial palynomorphs, which recovered from the examined successions, suggests a subtropical to tropical vegetation cover near the study area.

The fern spores symbolized by pteridophytes (e.g. *Deltoidospora*) occurs on wet lowlands, where there is a local pteridophyte vegetation that were found across all of the Salam-53 borehole samples [**60**]. Despite this, the presence of *araucariacean* pollen indicates the occurrence of conifer forests in rather dry hinterlands. [**5**, **60**, **61**].

Furthermore, the quantity of pollen grains *Classopollis*, which are well-known generated by plants of xerophyte, is thought to be a marker of dry climatic conditions [62, 63].

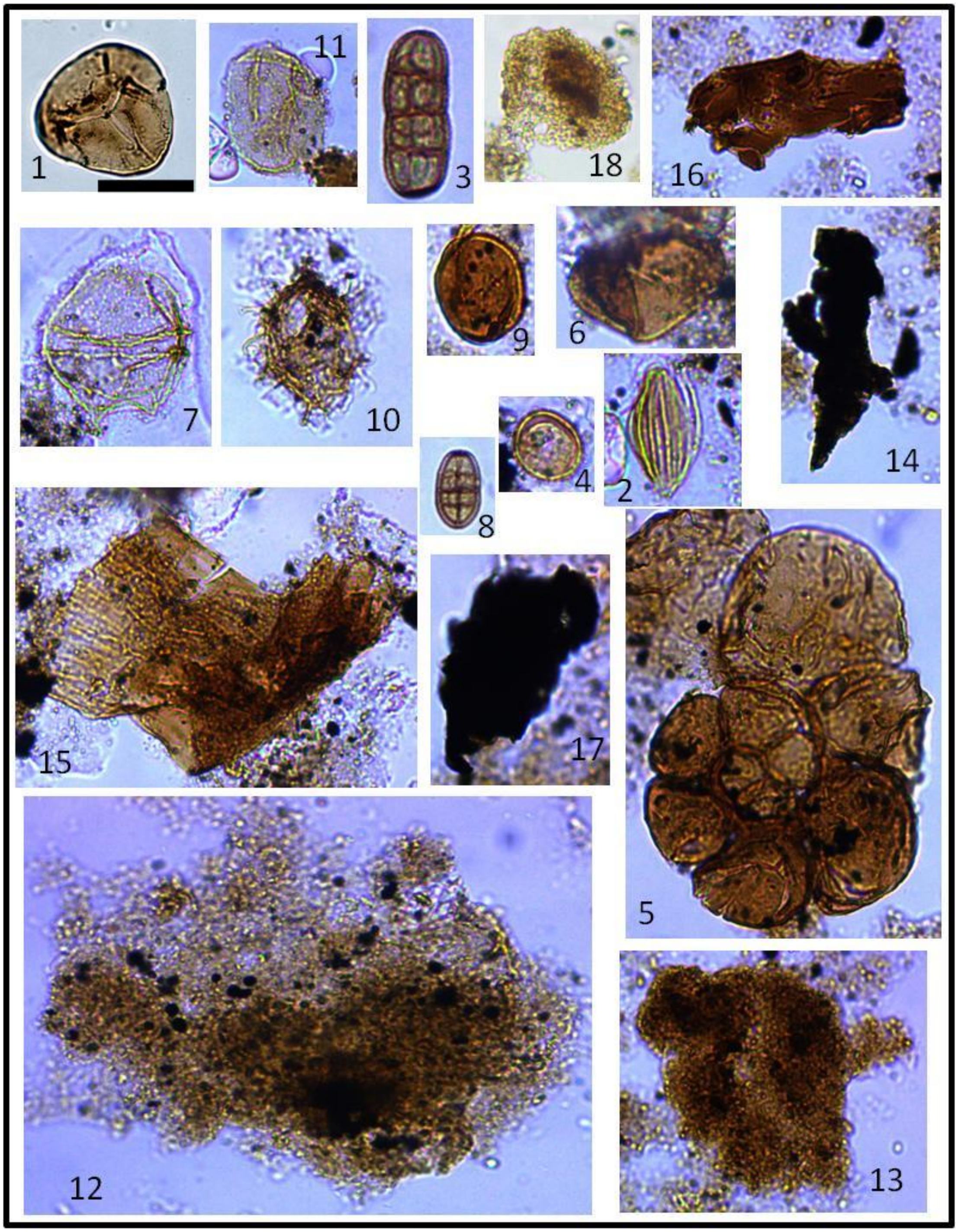


**Plate (1):** 1- *Deltoidospora sp.,* Depth: 6040 A, no.1, Indices: 23/85, 2-*Ephydripites,* Depth: 5320 A, no.7, Indices: 12.2/91, 3- Fungal spore, Depth:4520 A, no.17, Indices:9/104.9, 4- *Exinopollinites,* Depth:4450 A, No. 19, Indices:10/114.5, 5- Foraminifera test legnines, Depth:4400 A, No.20, Indices:15.5/80.6, 6- *Triplanosporites* sp., Depth: 6020 A, no.3, Indices: 22.5/84.8, 7- *Subtilisphaera senegalensis,* Depth: 3730 A, No.25, indices:5.5/93.4, 8- Fungal spore, Depth: 2900 A, no.27, Indices:6.7/98.6, 9-Cycadopites, Depth: 2880 A, no.28, Indices:22.6/100.5, 10- Florentina berrna, Depth: 3840 A, No.22, indices: 17/114.5, 11- *Arucariacites australis,* Depth: 3730 A, Sample no: 25, Indices: 4.5/107.4, 12-Amorphous organic matter, Depth: 4390 A, Sample no: 21, Indices: 10/117, 13- Amorphous organic matter, Depth: 2880 A, no.28, Indices:20/100, 14-Black Wood, Depth: 2880 A, no.28, Indices:12/90, 15- Brown wood, Depth:3720 A, No.26, Indices:14/104, 16- Brown wood, Depth:2880 A, no.28, Indices:13/94, 17- Black Wood, Depth: 2660 A, no.30, Indices:20/102, 18- *Afropollis jardinus,* Depth: : 2880 A, no.28, Indices:11/91.

**Table 1:** Key to palynofacies fields indicated in the ternary APP diagram (Simplified from [32]).

| Palynofacies field and environment | | Comments | Spores: Bisaccate | Microplankton | Kerogen type |
|---|---|---|---|---|---|
| VII | Distal dysoxic - anoxic shelf | Moderate to good AOM preservation. Low to moderate palynomorphs.Dar-coloured slightly biotrubated mudstones are typical. | Low | Moderate to common dinocysts dominated | II (oil prone) |
| VI | Proximal suboxic-anoxic shelf | High AOM preservation due to reducing basin conditions. Absolute phytoclast content may be moderate to high due to turbiditic input and/or general proximity to source | Variable low to moderate | Low to common dinocysts dominant | II (oil prone) |
| IX | Distal suboxic-anoxic basin | AOM-dominant assemblages. Low abundances of palynomorphs partly due to masking. Frequently alginate-rich. Deep basin or stratified shelf sea deposits, especially sediments starved basins. | Low | Generally low, prasinophyte often dominant | II ≥ I (highly oil prone) |

The hypothesis during the late Cenomanian indicate palaeoclimate of aregional subtropical based on the existence of pollen grains of *Afropollis* and *Elaterosporites* [**34**, **61**, **64**] and are analogous to Albian-Cenomanian Elaterate Phytogeographic Province of palaeosubtropical to palaeotropical African and north South American areas, where this province is defined by a warm, arid to semi-arid environment e.g. [**34**, **64**, **65**].

The presence of xerophytes *Ephredripites* and *Classopollis* [**18**, **60**, **66**] suggests drier conditions. The differences in percentage frequency of terrestrial palynomorphs are primarily influenced by changes in sedimentation trends (i.e. transgression-regression), which are regarded as more important than any other ecological parameters on land because these fern spores exhibit taxonomic stability across all studied sections [34]. The overall picture is of a significant terrestrial input into a near-shore marine context typified by large scale dry and arid biotopes, and deposition occurred closer to the beach with at least some marine impact.

## 4 Conclusion

The palynofacies analysis of the upper Bahariya, Abu Roash, and Khoman formations of the studied borehole of Salam-53, that located in the Shushan basin, northern western Desert, Egypt has led to the following conclusions:

This study's paleoenvironmental conclusions are mostly based on changes in the bulk composition of palynofloras and palynofacies, as well as the botanical affinities of terrestrial palynomorphs. There are two forms of palynofacies. The first palynofacies, which denotes the upper Bahariya besides the "G" to "C" members of the Abu Roash formations (samples 1-20), was deposited in a proximal inner shelf setting of prevailing conditions of reducing (suboxic-anoxic), which certified local oxic-dysoxic conditions occasionally through a late Cenomanian-Turonian marine transgression, which was a result of global eustatic sea level rise. The second signifies ("B" besides "A" members) the upper Abu Roash and Khoman formations (samples 21-28), which deposited in medium shelf settings during a significant worldwide Turonian-Maastrichtian marine transgression under the same prevailing reducing (suboxic-anoxic) conditions.

The presence of local pteridophyte and conifer flora suggests a paleoenvironment in the arid hinterlands with parent plants near the well site under a warm and rather dry subtropical palaeoclimate.

## 5 Acknowledgements

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