Tournaisian to Early Permian Miozonations of the Western Desert, Egypt

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Abstract: Well preserved miospores have been recovered from the Carboniferous - Permian succession of Sifa-1 and Miswag-1 wells located at the western and central parts of the Western Desert. The data obtained from the studied wells enable to distinguish five miozones represent a continuous sedimentation from the Tournaisian to the Early Permian. The Tournaisian – Visean miospores are characterized by pseudo – saccate , cingulate , and cavate (*Vallatisporites , Spelaeotriletes*) spores. The Upper Visean is characterized by the occurrence of *Lycospora pusilla* and many pseudo-zonate and cavate spores. The Namurian is characterized by the first appearance of monosaccate pollen. Meanwhile the Westphalian is characterized by the first occurrence of bisaccate pollen which became predominant in the Upper Carboniferous and Lower Permian.

[EL Shamma, A.A., Tarek F. Moustafa and Hosny, A. M. **Tournaisian to Early Permian Miozonations of the Western Desert, Egypt.** *J Am Sci* 2012;8(12):1530-1544]. (ISSN: 1545-1003). http://www.jofamericanscience.org. 205

Keywords: Tournaisian, Miozonations, monosaccate pollen, bisaccate pollen and pseudo- zonate.

1. Introduction

Some papers about the Carboniferous microfloras have been issued on Sinai and Gulf of Suez region by Saad (1965), Omara & Schultz (1965), Sultan (1977), Eames (1984), Kora & Schultz (1987), Aboul-Ela (1989), Kora(1993), Abdel Mohsen *et al.* (2001) and Atawy (2003).

Studies on the Palaeozic palynomorphs of the Western Dessert have started to emerge since the first trial of Schrank (1984 and 1987) in Foram-1 well. Gueinn & Rasul (1986) had established 15 biozones from about eleven wells drilled in the Western Desert ranging in age from Middle Cambrian to Early Permian.

El-Shamma *et al.* (1996) recognized five broad-based palynological zones ranging in age from early Visean to Early Permian encountered in Faghur-1 and NWD-302-1 wells. The present study could be considered as a continuous effort to identify the miospore content of the Carboniferous-Permian sediments in the study wells, elucidate their age assignment based on diagnostic taxa, and correlate them with other localities in North Gondwana and Tethyan Realm.

2. Stratigraphic Outline and Materials

The Palaeozoic succession in north Western Desert has initially been classified into rock units by Norton (1967) who applied some names used in the rock stratigraphy of the Libyan Palaeozoic to the Western Desert.

In 1972, Mohsen and Farid showed that the Norton's classification does not seem to be applicable to the Palaeozoic section in the Western Desert. They subdivided the Palaeozoic rocks from base upward into the Zeitun Formation (Cambrian-Silurian), Kohla Formation (Devonian) and Um Bogma Formation (Lower Carboniferous). They also distinguished three Permo-Carboniferous formations namely Rod El-Hamal, Abu Darag, and Aheimer.

Paleo services (1986) provided the most applicable and detailed lithostratigraphic subdivisions for the Palaeozuic sequence in the Western Desert. This classification includes two formal lithogroups, both of them have proven easily recognizable in the subsurface.

(A) Siwa Group

It ranges in age from early Mid Cambrian to Late Silruian and could be subdivided into three formations:

1. Shifah Formation (Mid Cambrian – Mid Ordovician)
2. Kohla Formation (Llandoverian- Ludlovian)
3. Basur Formation (mid- Late Ludlovian)

(B) Faghur Group

It is composed mainly of sandstone, siltstone, mudstone and carbonate. It lies unconformably on the Siwa Group, and is unconforambly overlain by Mesozoic clastics. The group is subdivided into four formations, from base to top:

1. Zeitun Formation (Gedennian- Early Carboniferous) Mudstones and siltstones are the most important lithologies in this formation in terms of bulk proportion. Lesser amounts of carbonaceous sandstone, limestone and dolomite are significant too.
2. Desouqy Formation (Tournaisian –Early Visean). The base and top of the formation are locally quite rich in claystone and limestone beds in between. Usually, however, the formation rests

unconformably on the Zeitun Formation. This period of non-deposition includes the Tournaisian, so that the earliest Visean is seen to overlie Famenian or older.

3. Dhiffah Formation (Visean-Late Namurian). A variety of lithologies characterize this formation. Mudstone and siltsone are volumetrically most abundant while the amount of interbedded sandstone becomes increasingly significant upwards. The formation abruptly overlies the Desouqy Formation, but no hiatus or unconformity is suspected.
4. Safi Formation (Late Namurian-Early Permian). This formation is only seen in few wells where post-Early Permian erosion has not entirely removed. It is characterized by the dominance of sandstone, and siltstone, with local minor mudstone bands. The base of the formation is taken at the top of the underlying Dhiffah Formation and is marked by an abrupt increase in the proportion of sandstone upwards. The top of the formation is marked by a major unconformity

The material examined during this study were obtained from two exploratory wells (Sifa- 1 and Miswag -1) located in the northern part of the Western Desert. Sifa -1 well was drilled by Arco in 1990 and is located at Lat, 29° 59' 15 N and Long. 25° 04' 04 E. Miswag -1 well was drilled by Amoco in 1970 and is located at Lat; 29° 21' 12 N, and Long. 28° 48' 06 E. (Fig -1). Samples for palynological investigation were taken mainly from ditch cuttings. Forty four samples are subjected to palynological treatment using the standard technique by HF. And HCl and short treatment with conc. HNO_3 as an oxidizing reagent and $Zn\ I_2$ as a heavy liquid separation. The quantitative analysis of the investigated slides is based on the counting of an average of 200 palynomorphs per sample. The specimens of various species were counted and recorded as: single (1), rare (2-4), frequent (5-10), common (11-19), and abundant (≥ 20).

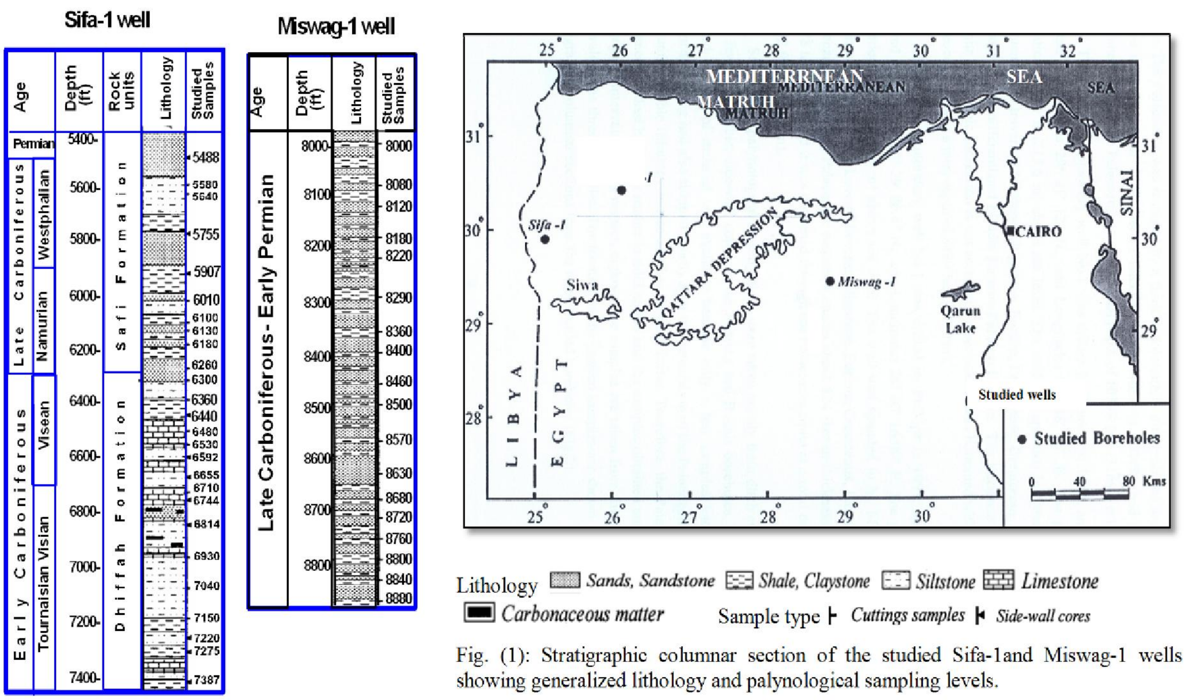


Fig. (1): Stratigraphic columnar section of the studied Sifa-1and Miswag-1 wells showing generalized lithology and palynological sampling levels.

Palynostratigraphy

The palynomorph associations in the studied borehole were derived mainly from cutting samples, with some side-wall cores. In a study based on well cuttings, the oldest occurrence of a species in a section or "species base" may be used as a guide and cannot be considered reliable, since it has been extensively complicated by frequent contamination and clearly demonstrated by the occurrence of down hole caving material thereby restricting the accuracy of palynostratigraphic interpretation. The youngest occurrence of a species in a section " species top" remains the most reliable datum to define zones and correlate wells.

A semi-quantitative counts in terms abundant, common, frequent, rare and single are plotted against sample depth on a distribution chart to illustrate the stratigraphic distribution of all the identified palynomorph species.

Miospores are the most abundant palynomorphs in the studied intervals. They are present in nearly all the productive samples, although not in equal abundance or diversity. Most of them are triletes spores. Pollen grains are dominated by monosaccate taxa. Bisaccates are represented at higher sample levels. The samples from Sifa-1 well yielded an excellent micrafloral assemblage, in terms of relative abundance and diversity. The studied interval from Miswage-1 borehole will be put in its correct stratighraphic position in comparison with data obtained from Sifa-1 borehole.

I- Sifa-1 Borehole

Twenty six samples between 7387 ft. and 5488 ft. are available for palynological investigation. The quantitative distribution chart (Fig. 2) shows a successive occurrence of different palynomorph species recorded at different stratigraphic horizons which enabled us to establish 5 broad based palynostratigraphic units.

Tournaisian? – Early Visean (SF-8):

Numerous miospores were recovered from the interval between 7387̀ to 6655̀. The most significant species include. *Vallatisporites verrucosus., V-vallatus, V-ciliaris, V-agadesi, Retusotriletes incohatus, Aratrisporites sahariensis, Spelaeotriletes arenaceus, S.balteatus, S.owensi, Raistrickia nigra, Cirratriradites rarus, Rugospora flexuosa, Verrucosisporites nitidus, Radiizonatus genuinus, Densosporites spinifer, D.variomarginatus, Diatomozonotrites fragilis, Grandispora echinata* and *Dictyotriletes* cf.*fimbriatus.*

Age assignment

Numerous miospore assemblage recognized from the Tournaisian deposits are well dated by marine faunas worldwide. Nevertheless, the North African sequence lack any stratigraphically diagnositic fauna. This means that there is no reliable palaeontologic evidence to prove the existence of the Tournaisian strata in the North African region. A striking similarity between the assemblage recovered herein and those of Grignani *et al.* (1992) from Al-Kufra Basin in southeast Libya can be noted (zone 12 and 13). The equivalent assemblages in Europe which were recorded by Higgs (1975) and Higgs *et al.* (1988) in Ireland; Higgs & Clayton (1984) in England; Higgs & Streel (1984) in Germany and Clayton *et al.* (1977) from the Lower Carboniferous strata of western Europe have many miospore species in common with the present assemblage of Sifa-1 well, although most of the European taxa are of long range.

The assemblage of Sifa-1 well contains numerous species of restricted vertical range which are known from different regions and permit interregional correlation. A comparison of the present assemblage with those of the same age in north Africa region reveals the common presence of similarity in the taxa associations as presented by Clayton & Loboziak (1985) and Loboziak & Clayton (1988) of early Visean of northeast Libya – both assemblages is characterized by *Spelaeotriletes owensi, S.balteatus, Radiizonatus genuinus, Vallatisporites agadesi, V.vallatus, Aratrisporites sahariensis, Cirratriradites rarus, Densosporites variomarginatus, Diatomozonotriletes fragilis* and *verrucosisporites nitidus*. The same association was reported before by Massa *et al.* (1980) in western Libya and dated as Early-Middle Visean., and by Loboziak *et al.* (1991) from the Amazon Basin of Brazil and was dated as late Tournaisian to early Visean.

The data obtained from the Visean strata of Egypt by Gueinn & Rasul (1986), Schrank (1987) from the Western Desert, and Kora & Schultz (1987) and Kora (1993) in Sinai are matched well the same result concluded herein . More confirmation for the Visean age for the present assemblage of Sifa-1 was noted by El-Shamma *et al.* (1996) from NWD-302-1 and Faghur-1 boreholes (Western Desert) as both associations comprise undoubtly Visean spores of *Spelaeotriletes owensi, S.balteatus, Aratrisporites sahariensis, Vallatisporites vallatus, V-agadesi, V.celeber, Punctatisporites* spp., *Diatomozonotriletes fragilis* and *Retusotriletes incohatus.*

Late Visean(SF-9):

A distinctive and rich miospore assemblage has been recovered from the stratigraphic interval between 6655 of 6480 ft. The base of this assemblage is marked by the first occurrence of *Lycospora pusilla, Densosporites annulatus and Spelaeotriletes giganteus.* Other taxa characterizing the preceding Lower Carboniferous sediments such as, *Vallatisporites vallatus, Retusotriletes incohatus, and Punctatisporites gibberosus are disappeared.*

The most common and striking species recorded herein include, *Vallatisporites ciliaris, V.agadesi, Verrucosisporites nitidus, Spelaotriletes owensi, S.triangulus, S.benghaziensis, Diatomozonotriletes fragilis, Aratrisporites sahariensis, Prolycospora rugulosa, Radiizonates genuinus, Densosporites* spp., and *Apiculiretusispora multiseta.*

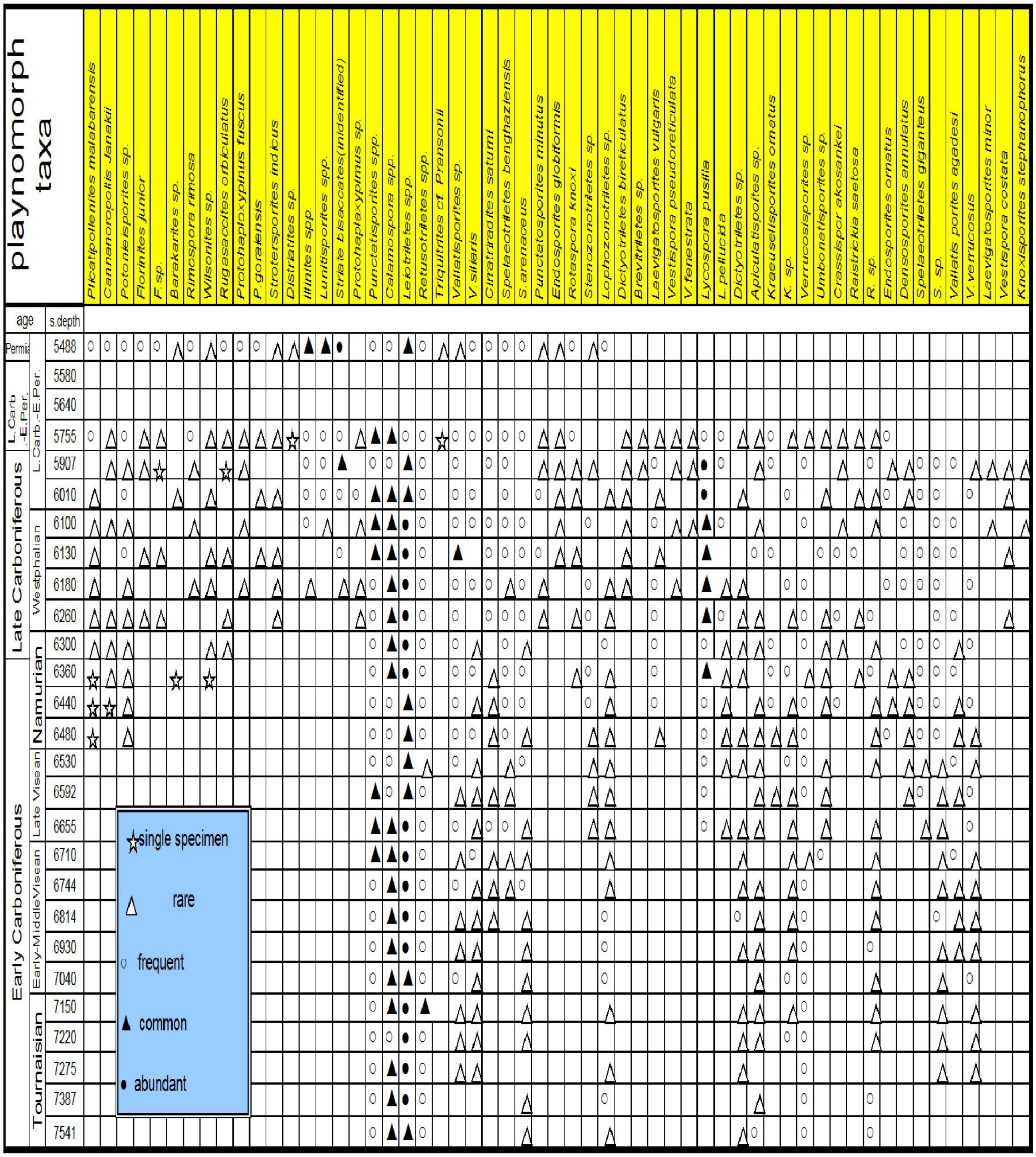
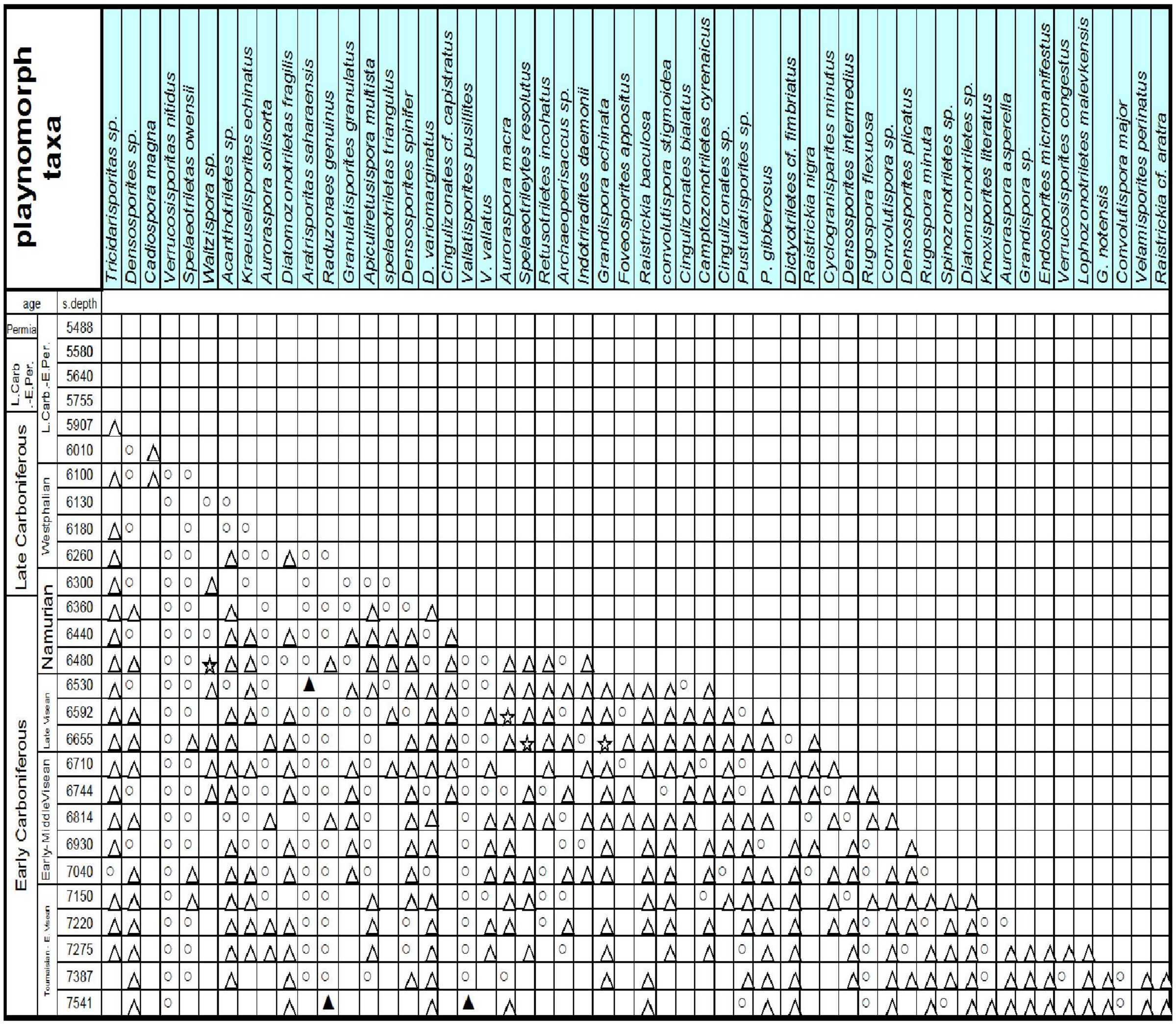


Fig. (2) Quantitative distribution chart of the palynomorph species recovered in Sifa – 1 borehole.



Cont. Fig. (2) Quantitative distribution chart of the palynomorph species recovered in Sifa – 1 borehole.

Age assignment

In north Africa, the first occurrence of *Lycospora pusilla* was considered by Massa *et al.*(1980), Coquel *et al.* (1988), Loboziak & Clayton (1988), and more recently by Coquel & Massa (1993) to occur in the late Visean. So, the first occurrence of this species at the base of the present interval could be taken to indicate a late Visean age.

Loboziak & Clayton (1988) recognized late Visean assemblage from northeast Libya (OA subzone "SG Biozone" and the lower part of RT Biozone) which is very close to the recovered assemblage from Sifa-1 well. A similar assemblage was reported by Loquel *et al.* (1995) from the Talak Formation, northern Niger; and from Saudi Arabia (Clayton , 1995). Information from the Algerian Sahara given by Lonzoni & Magloire (1969) and by Attar *et al.* (1980) suggests that the assemblages from the Visean of this part of north Africa is similar to that recorded here in. They recorded abundant specimens of *Grandispora balteata (= Aratrisporites saharaensis)* in zone IV of Visean age. In the upper part of the zone many significant species appeared such as: *Radiizonatus genuinus, Spelaeotriletes owensi, S.triangulus, Vallatisporites agadesi* and *V.ciliaris.* In zone V, of late Visean to Namurian age, Lycospora is first recorded, although it is relatively rare, and becomes increasingly common upwards.

More recently, Melo & Loboziak (2003) reported the Visean palynomorphs assemblage in

Amazon basin, Brazil which is distinguished by most of the pre–mentioned taxa

Namurian (SF-10):

A Namurian palynoflora assemblage has been recovered from the stratigraphic interval between 6480̀ and 6260̀. The base of this interval is marked by the first occurrence of monosaccate pollen *Potoneisporites spp., Plicatipollenites malabarensis, Florinites spp.,* and *Cannanoropollis janakii,* associated with some spores attributed distinctly to the Silesian time such as *Crassispora kosankei, Rotaspore knoxi, Endosporites ornatus, Laevigatosporites vulgaris* and *Raistrickia satosa*. Many of miospores taxa recorded from the preceding Lower Carboniferous are still persisted here, meanwhile others are absent. The most disappearing taxa include; *Aratrisporites sahariensis,Radiizonates genuinus, Spelaeotriletes triangulus, Prolycospora regulosa, Diatomozonotriletes fragilis,* and *Apiculiretusispora multiseta*.

Age assignment

As concluded by Clayton *et al.* (1990) the monosaccate pollen are considered the most significant taxa do appear in basal Namurian sections in the *Monilospora* and *Aratrisporites sahariensis* province. An additional evidence to confirm the age assignment of this interval could be supported by the range of *Rotaspora knoxi.* This species is regarded as a characteristic miospore form for the Visean and Namurian assemblage throughout many palynoflora province worldwide (Owens *et al.,* 1978).

A similar assemblage to that recorded herein was reported by Clayton & Loboziak (1985) and later by Loboziak & Clayton (1988) from northeast Libya (upper part of RT Biozone and basal part of MJ Biozone) which was refered to the Serpukhovian (= Namurian) age.

From north Niger, Coquel *et al.* (1995) recorded an assemblage with *Tricidarispora* spp., *Vallatisporites agadesi, Spelaeotriletes arenaceus*, *S.owensi*, *Densosporites spinifer* and sporadic *Lycospora pusilla*. No monosaccate pollen taxa were recorded.

Clayton (1995) assigned a Namurian age from the northwest part of Saudi Arabia for an assemblage based on comparable criteria with the RT and MS Biozones in northeast Libya.

On the other hand, the Namurian assemblage described by Neves *et al.* (1972) and Ownes *et al.* (1977) from England; Clayton *et al.* (1977) from western Europe, Ownes *et al.* (1984) from North America; Kemp *et al.* (1977) from Australia; all yielded dissimilar palynomorphs. Consequently, detailed comparison of the Sifa-1 assemblage with those mentioned above seems inappropriate.

West phalian (SF-11):

The West phalian assemblage which has been recovered from the stratigraphic interval between 6260̀ to 6010̀ is characterized, in general terms, by a relatively high diversity of palynoflora species. Monosaccate pollen become more frequent and belonging mainly to taxa seen earlier, but also include *Barakarites* sp., *Florinites* sp., and *Rimospora rimosa.*

Poorly represented bisaccate pollen taxa appeared at the base of this interval include *Illinites* sp., and *Protohaploxypinus* sp. other miospore species which appear at the base and ranging higher up include *Vestispora* spp., *Laevigatosporites minor*, *Knoxisporites stephanophorus, Endosporites globiformis, Cirratriradites saturni* and *Cadiospora magna.*

Extinct taxa within the assemblage include *Verrucosisporites nitidus* and *spelaeotriletes owensi*.

Age assignment

The first occurrence of bisaccates began in the uppermost part of the *Radiizonates aligerens* (RA) Biozone which was assigned to the upper part of Westphalian A in Western Europe (Clayton *et al.,* 1977), whilst the first occurrence of those bisaccate taxa is recorded in the *Endosporites globiformis* (Eg) miospore zone which corresponds to the basal part of Westphalian B in the Polish margin of the east European platform (Kmiecik, 1986).

The species *Cirratriradites saturni* which has been scarcely recorded in the Namurian is a more frequent component in the basal Westphalian *Triquitrites sinani- Cirratriradites saturni* (SS) Zone identified from the western European zonal scheme. *Endosporites globiformis*, a species which appeared in the RA Zone and became more frequent in the younger deposits worldwide. *Cadiospora magna*, a species with a very limited stratigraphic distribution which in most regions spans the Westphalian D to the basal part of Stephanian sequence (Ravn, 1986).

Comprehensive palynological studies on the Late Carboniferous palynostratigraphy of the adjacent regions are few and any conclusions drawn are often speculative, being based on the absence of any adequate independent biostratigraphic control.

The most comprehensive scheme for palynological zonation of the Carboniferous deposits in north Africa is that proposed by Massa *et al.* (1980) and Coquel *et al.* (1988) from the Ghadamis Basin in west Libya, and from the Cyrenaican platform in northeast Libya by Loboziak & Clayton (1988) , There is an agree between these authors that the Westphalian-early Stephanian assemblages are characterized by the occurrence of monosaccate and some taeniate bisaccate pollen taxa, that is beside spores of *Cirratiradites rarus, Laevigatosporites* *vulgaris, Endosporites glabiformis* and *Vestispora fenestrata.*

The same result has been obtained from the Westphalian D from the northwestern part of Saudi Arabia by Ownes & Turner (1995).

From the foregoing discussion, the same age (Westphalian) of these assemblages can easily by attributed to the present assemblages of Sifa-1 well.

Late Carboniferous-Early Permian (SF-12):

The palynological assemblage of this age is recovered within the stratigraphic interval from 6010̀ to 5488̀. The assemblage is characterized in general by a dramatic increase in the number of bisaccate forms and a corresponding decrease in diversity and abundance of miospores.

This change in the palynofloras may be attributed to the impact of the glacial episode which began in the Late Palaeozoic (Pan-Gondwana glaciations) and continued until the late Asselian.

Taxa extending their range in this interval mainly include , *Cirratriradites saturni, Lycospora pusilla, Spelaeotriletes giganteus, S-benghaziensis, Rotaspora knoxi, Vestispora* spp*., Cadiospora magna, Endosporites ornatus* and *Laevigatosporites vulgaris*. Bisaccate pollen taxa recorded in the preceding Westphalian interval are still the predominant species here

Age assignment

The age relationship and palynostratigraphy of the Upper Carboniferous-Lower Permian sediments are probably the least understood part of the Late Palaeozoic sequence in the sedimentary basins of the Western Desert and adjacent regions.

This problem remains largely unresolved, whilst a degree of palynostratigraphic order has developed from the examination of palynomorph assemblage of this stratigraphic sequence in Euroamerican province and in parts of the Gondwana province as Australia and India. Although specific correlation between most of these palynostratigraphic zones are not yet possible, the palynological evidences indicate that broad structure of the terrestrial floras was greatly modified in a relatively short period of time near the end of the Carboniferous or the beginning of the Permian period. This major plant evolutionary event is marked by a sharp increase in the abundance and diversity of gymnosperm pollen specially taeniate forms near the base of the Orenburgian stage and its stratigraphic equivalent in USSR, and within the Autunian in Western Europe, and with the base of the Wolfcamian stage in the United States.

The incoming of Distriatites pollen in the present assemblage could be a well mark datum corresponding to the Carboniferous/Permian boundary and thus, the uppermost productive sample (5488̀) in the present sequence would be attributed to definitive Permian age.

The age can be confirmed by comparing the present assemblage with the data which obtained from northeast Libya reported by Brugman *et al.* (1985), Brugman *et al.* (1988) and Loboziak & Clayton (1988).

The Libyan assemblage is characterized by dominance of saccate pollen *Potonieisporites* spp*., Cannanaropollis janakii, Plicatipollenites malabarensis, Barakarites* spp*., Rimospora rimosa, Illinites* spp*., Protohaploxypinus* spp*.,* and *Distriatites* sp *with Lycospora pusilla, Spelaeotriletes* spp*., Endosporites ornatus, Laevigatosporites vulgaris.* (assemblage zone A of Ghazelian? – Asselian age of Brugman *et al.,* 1988)

The same association was reported by Loboziak & Clayton (1988) in Strotersporites indicus- *Protohaploxypinus goraiensis* (IG) Biozone which is referred also to the Ghazelian-Asselian age. So, it can conclude that the assemblages from the Egyptian Western Desert and that of northeast Libya are palynologically similar, and a Ghzelian-Asselian age can be postulate for the Sifa-1 interval from 6010̀ to 5488̀m.

II- Miswag–1 Borehole

The Miswag -1 borehole was drilled in 1970 by the Amoco Oil Company near the eastern edge of the Qattara Depression. It was bottomed at a total depth of 8889 feet. The studied interval attains about 880 feet which is dominated by sandstones with interbeds of shales.

Eighteen cuttings samples obtained from the interval between 8000 to 8880 feet have been palynologically examined. The samples 8000, 8720 and 8880 feet are barren. All the productive samples contain several taxa of Late Carboniferous/Early Permian age, with some cavings from younger horizons.

Miospores are more diverse whereas monosaccate pollen are abundant, Bisaccates are less diverse in composition. The stratigraphically diagnostic taxa are listed in the distribution chart (Fig.3)

Stratigraphic Palynology

Fifteen productive samples contained monotonous assemblage which is dominated by monosaccate pollen and highly ornamented miospores. The most significant species are *Plicatipollenites malabarensis, Rimospora rimosa, Cannanoropollis janakii, Florinites junior, Florinites* sp*., Potonieisporites* spp*., Barakarites* sp*., Laevigatosporites vulgaris, Punctatosporites minutus, Brevitriletes* sp*., Vestispora* sp*., Spelaeotriletes* spp*., Vallatisporites* spp., *Pustulatisporites* sp., *Spelaeotriletes triangulus* and *Stenozonotriletes simplex*. This assemblage also contains a sparse number of bisaccate pollen which have been provisionally referred to the genera *Protohaploxypinus, Illinites, Limitisporites* and *Distriatites.*

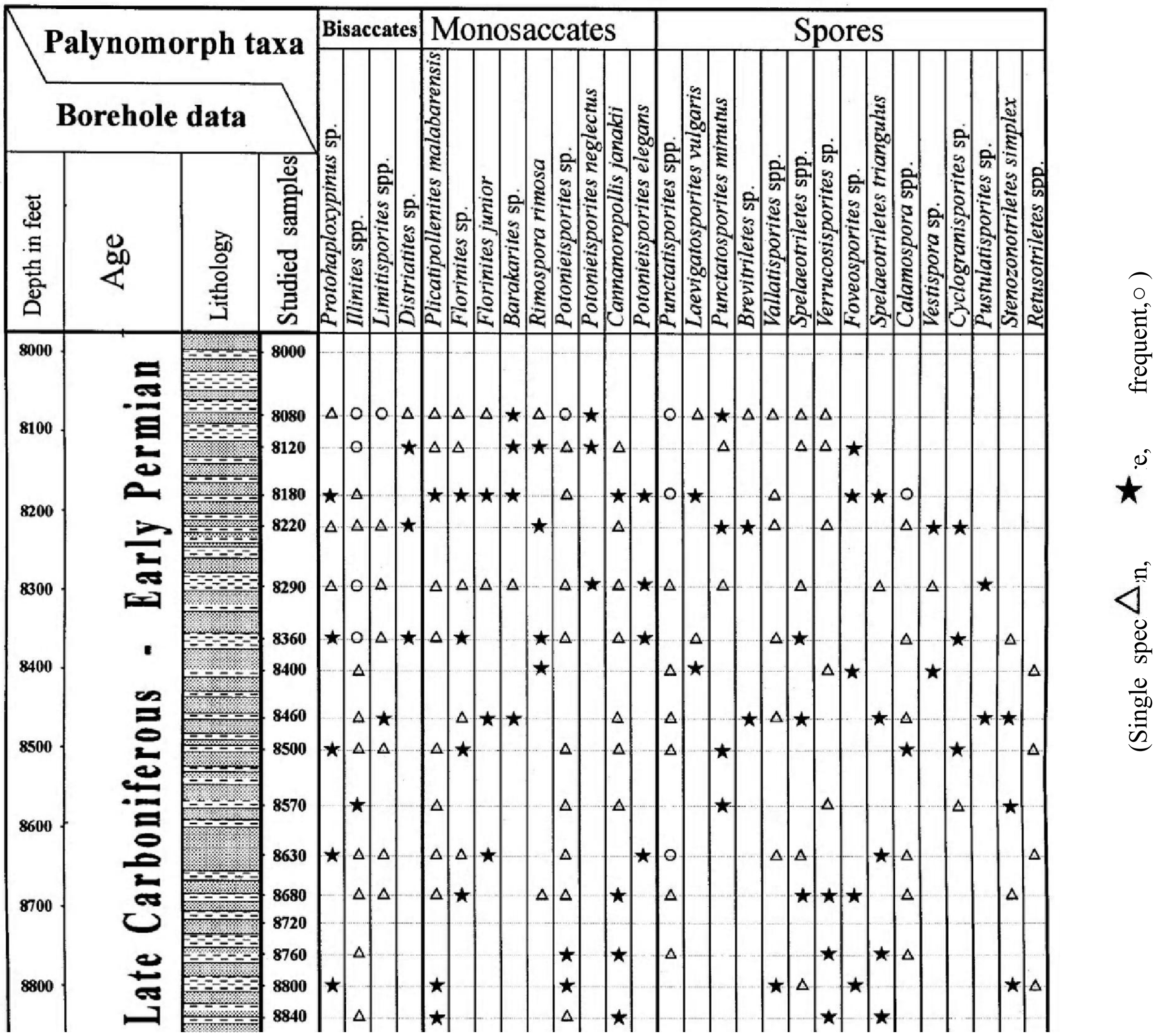


Fig. (3) Quantitative distribution chart of the palynomorph species recovered in Miswag-1 borehole

This association is closely comparable to the assemblage recorded in the undifferentiated Late Carboniferous / Early Permian age identified from Sifa–1 borehole. This allows us to postulate Late Carboniferous to Early Permian age to the interval 8080–8840 ft in the Miswag–1 borehole.

The stratigraphic range chart of the significant recovered taxa in the two boreholes is shown in fig(4).

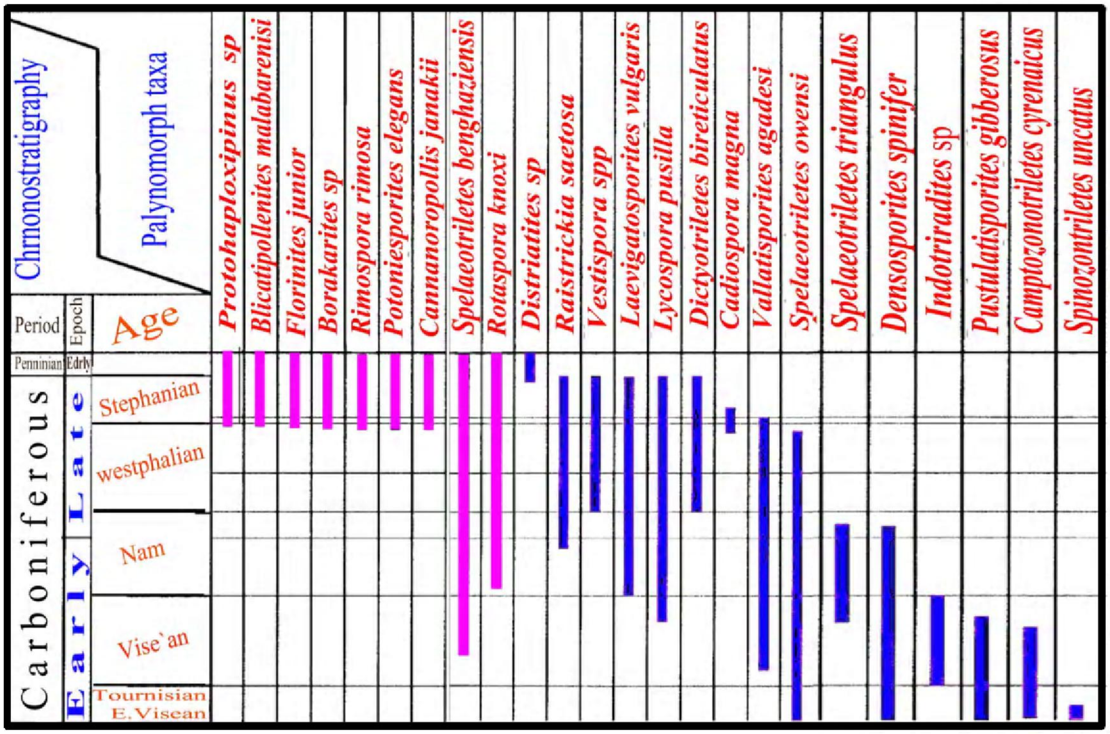


Fig. (4) Stratigraphic range chart of the significant palynomorph taxa in the studied Carboniferous sequence in Sifa-1and Miswag-1 Boreholes in Western Desert, Egypt.

Climate and Spores Evolution

The Lower Carboniferous miospores are mainly constituted of taxa of terrestrial origin such as: *Punctatisporites, Vallatisporites, Spelaeotriltes, Verrucosporites, Raistrickia* and *Densosporites*. Laevigati forms (Calamaspora and Retusutriletes) and cingulizonate forms (*Vallatisporites* , *Spelaeotriletes* and *Lycospora*) occur in higher abundance and high diversity.

A gradual increase of the spores diversity from the lower part of the Tournaisian upwards is recognized. These taxa reflect more evolution in the land plants and may attributed to moisture tropical climate during the Early carboniferous as indicated by Raymond (1985), he mentioned that this climate is providing excellent growing conditions for numerous vascular land plants in association with abundant peat deposits over large areas in the world.

The Namurian sedimentary sequence is characterized by fairly decrease in the spore diversity , that is associated with frequent occurrence of monosaccate pollen such as *Plicatipollenites* , *Cannanaropollis* , *Potoneisporites* …. etc. which indicate that the palaeoclimatic conditions become more drier and prevailing of xerotropic conditions (Raymond, 1985)

Schrank (1987) concluded that the Lower Carboniferous terrestrial plants in the Western Desert are widely distributed over many sites in which they grew. Although the pteridophytes do not provide any conclusive evidence on the palaeoclimate because the pore- producing plants are largely unknown, yet the existence of moist habitates and of a worm – temperature may be assumed.

A prevalence of bisaccate pollen and a corresponding decrease of spores is consider a marked stricking feature at the end of the Carboniferous time and the beginning of the Permian in the present study. Balme (1980) mentioned that the introduction of bisacate pollen was globally synchronous and induced by rapid global climatic amelioration following the glaciations of Gondwana that took place nearly close the end of Late Carboniferous time. In the present study the pronounced dominance of bisaccate forms in the upper most horizon has been interpreted as an indication that drier climate condition took place with encroachment of upland vegetation into the site of sedimentation . spores were also being deposited at that time , and were perhaps derived from a low land mesophytic and hydrophilous plants community

This idea was confirmed also by Habib (1968) and Cecil *et al.* (1985) who mentioned that the palaeoclimate began to change gradually by the Late Carboniferous with a reduction in moisture from over – wet tropical to seasonal tropical. This trend was caused by a number of factors including reduced rainfall, decline of arborecent lycopsides and the increased dominance of herbaceous and fern plants.

This may cause admixture of several gymnospermous saccate pollen derived from upland environments and several spore elements derived from lowland communities.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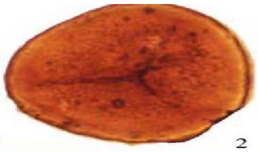
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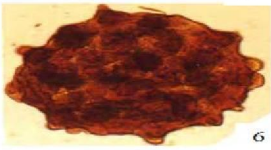
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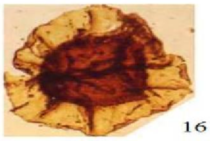
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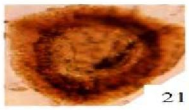
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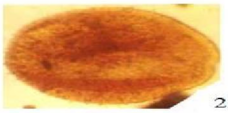
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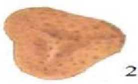
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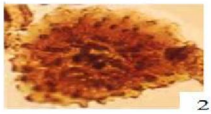
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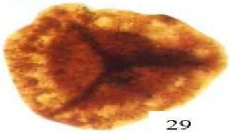
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Fig. 1: ***Ambitisporites*** sp.
Fig. 2: ***Punctatisporites*** sp.
Fig. 3: ***Calamospora*** sp.
Fig. 4: ***Verrucosisporites nitidus*** Playford, 1960 .
Fig. 5: ***Pustulatisporites*** sp.
Fig. 6: ***Pustulatisporites gibberosus*** (Hacquebard) Playford, 1964
Figs.7,8: ***Apiculiretusispora multiseta*** (Luber) Butterworth & Spinner, 1967
Fig. 9: ***Aratrisporites saharaensis*** Loboziak, Clayton & Owens, 1986
Fig. 10: ***Rugospora flexousa*** (Jushko) Streel, 1974
Fig. 11: ***Radiizonates genuinus*** (Jushko) Loboziak & Alpern, 1978
Fig. 12: ***Archaeoperisaccus*** sp.
Fig. 13: ***Acinosporites*** sp.
Fig. 14: ***Vallatisporites pusillites*** (Kedo) Dolby & Neves, 1970
Fig. 15: ***Endosporites micromanifestus*** Hacquebard, 1957
Fig. 16: ***Camptozonotriletes cyrenaicus*** Loboziak & Clayton, 1988
Fig. 17: ***Retispora lepidophyta*** (Kedo) Playford, 1976
Fig. 18: ***Stenozonotriletes*** sp.
Fig. 19: ***Densosporites intermedius*** Butterworth & Williams, 1958
Fig. 20: ***Densosporites spinifer*** Hoffmeister, Staplin & Malloy, 1955
Fig. 21: ***Cingulizonates bialatus*** (Waltz) Smith & Butterworth, 1967
Fig. 22: ***Umbonatisporites*** sp.
Fig. 23: ***Stenozonotriletes simplex*** Naumova, 1953
Fig. 24: ***Tricidorisporites*** sp.
Fig. 25: ***Vallatisporites vallatus*** Hacquebard, 1957
Fig. 26: ***Vallatisporites ciliaris*** (Luber) Sullivan, 1964
Fig. 27: ***Vallatisporites agadesi*** Loboziak & Alpern, 1978
Fig. 28: ***Vallatisporites verrucosus*** Hacquebard, 1957
Fig. 29: ***Spelaeotriletes triangulus*** Neves & Owens, 1966
Fig. 30: ***Spelaeotriletes owensii*** Loboziak & Alpern, 1978

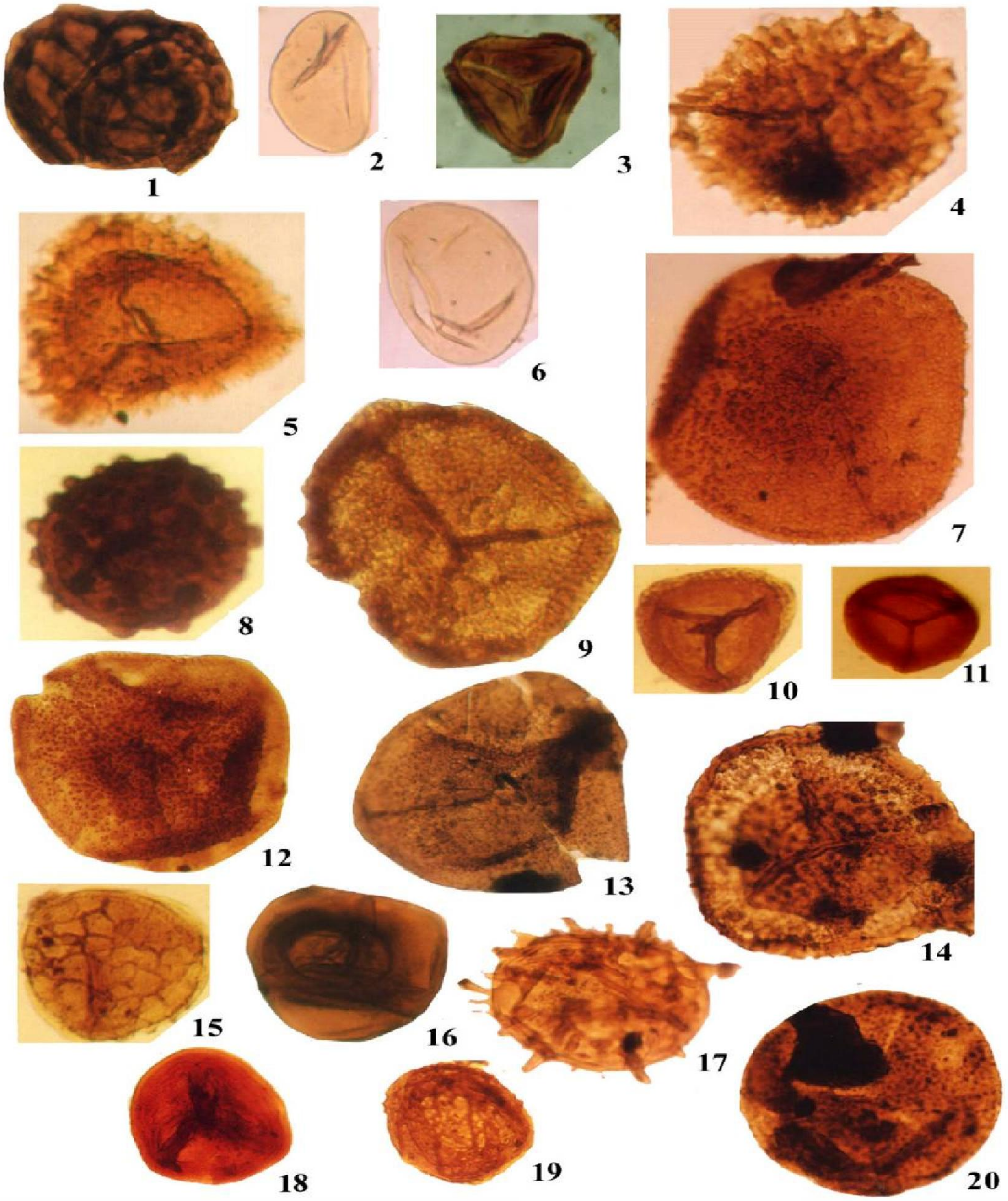

Fig. 1: ***Vestispora costata*** (Balme) Bharadwaj, 1957
Fig. 2: ***Laevigatosporites minor*** Loose, 1934
Fig. 3: ***Rotaspora knoxi*** Butterworth & Williams, 1958
Fig. 4: ***Kraeuselisporites echinatus*** Owens, Mishell & Marshall, 1976
Fig. 5: ***Kraeuselisporites ornatus*** (Neves) Owens, Mishell & Marshall, 1976
Fig. 6: ***Laevigatosporites vulgaris*** Ibrahim, 1933
Figs. 7, 12 : ***Spelaeotriletes benghaziensis*** Loboziak & Clayton, 1988
Fig. 8: ***Raistrickia baculosa*** Hacquebard, 1957
Fig. 9: ***Spelaeotriletes giganteus*** Loboziak & Clayton, 1988
Figs.10, 11: ***Lycospora pusilla*** (Ibrahim) Somers, 1972
Fig. 13: ***Spelaeotriletes arenaceus*** Neves & Owens, 1966
Fig. 14: ***Spelaeotriletes*** sp.
Fig. 15: ***Dictyotriletes bireticulatus*** (Ibrahim) Potonié & Kremp, 1954
Fig. 16: ***Knoxisporites stephanophorus*** Love, 1960
Fig. 17: ***Raistrickia saetosa*** (Loose) Schopf, Wilson & Bentall, 1944
Fig. 18: ***Cadiospora magna*** Kosanke, 1950
Fig. 19: ***Vestispora lucida*** (Butterworth & Williams) Potonié, 1960
Fig. 20: ***Apiculatisporites*** sp.


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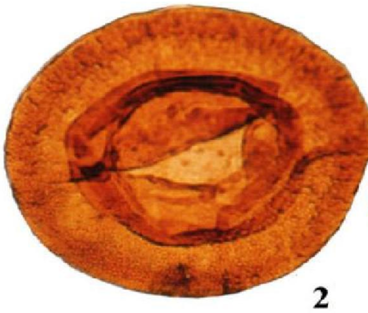
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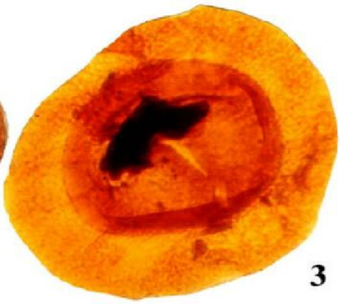
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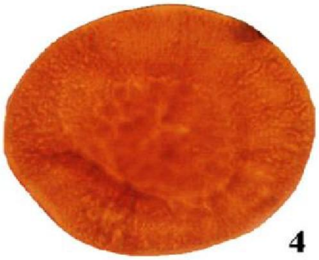
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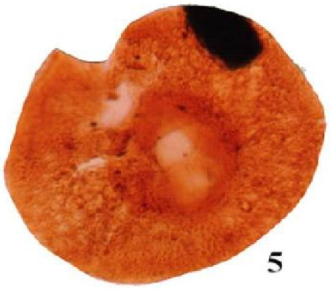
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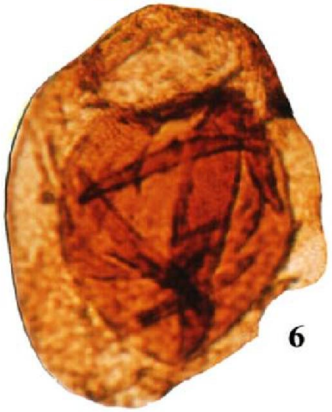
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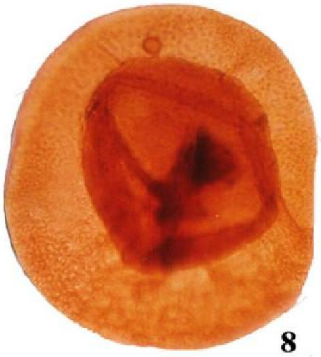
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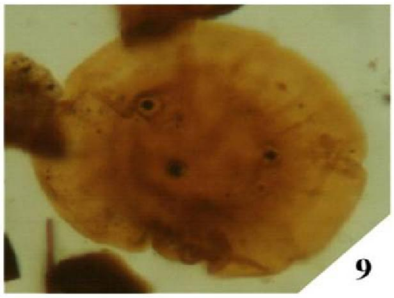
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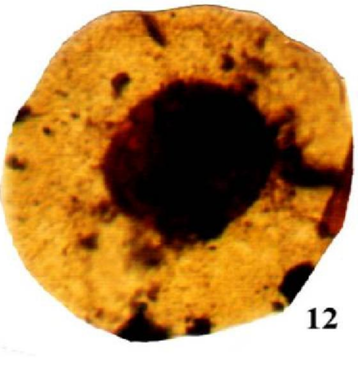
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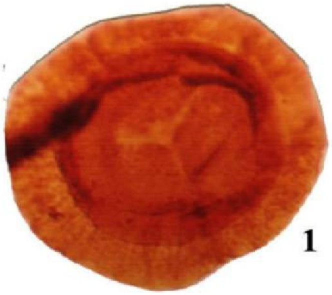
Fig. 1: ***Wilsonites*** sp.
Figs. 2, 3: ***Plicatipollenites malabarensis*** (Potonié & Sah) Foster, 1975
Figs. 4, 5: ***Cannanoropollis janakii*** Potonié & Sah, 1958
Fig. 6: ***Potonieisporites elegans*** (Wilson & Kosanke) Wilson &
Fig. 7: ***Potonieisporites neglectus*** Potonié & Lele, 1961
Fig. 8: ***Florinites*** sp.
Fig. 9: ***Rugasaccites orbiculatus*** Lele & Maithy, 1969
Figs. 10, 11: ***Potonieisporites*** sp.
Fig. 12: ***Florinites junior*** Potonié & Kremp, 1956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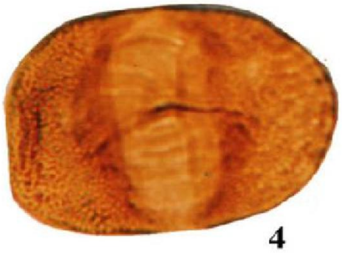
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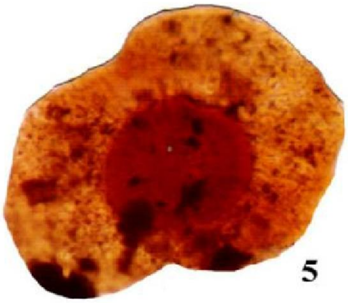
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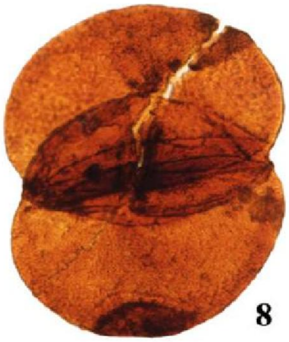
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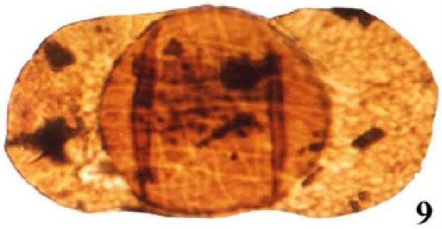
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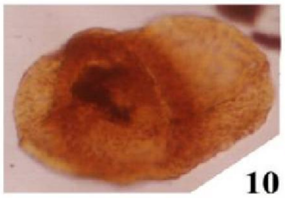
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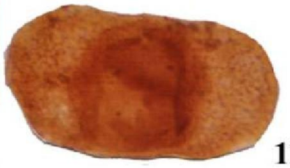
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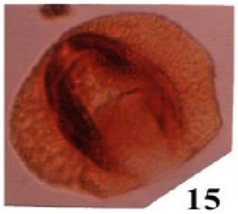
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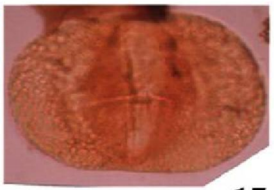
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Fig. 1: ***Barakarites*** sp
Fig. 2: ***Protohaploxypinus*** sp
Fig. 3: ***Florinites*** sp.
Fig. 4: ***Strotersporites indicus*** Tiwari, 1965
Figs. 5.6: ***Rimospora rimosa*** Lele & Maithy, 1969
Figs. 7.8: ***Protohaploxypinus fuscus*** Bharadwaj, 1962
Fig. 9: ***Protohaploxypinus goraiensis*** (Potonié & Lele) Hart, 1964
Figs. 10.11: ***Illinites*** spp
Figs. 12.13: ***Limitisporites*** sp
Figs. 14.15. 17: ***Disaccites*** (unidentified)
Fig. 16: ***Disaccites*** sp

Summary

The data obtained from the studied wells enabled to distinguished five miozones represent a continuous sedimentation from Tournaisian to the Lower Permian. The study revealed that, a significant part of the Tournaisian rocks has been recognized on the basis of palynological evidence.

The gradual increase of the spore diversity from the Tournaisian upwards reflects the evolution in the land plants and may attributed to moisture tropical climate during the Early Carboniferous.

The Late Carboniferous –Early Permian assemblages in most regions show significant global changes in palynofloras. The introduction of bisaccate pollen is result of global climatic amelioration following the glaciations that take place nearly close the end of Late Carboniferous time in the Gondwana.

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