PALYNOLOGICAL AND PALEOENVIRONMENTAL ANALYSES OF SELECTED SHALE SAMPLES FROM ORANGE BASIN, SOUTH AFRICA

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ABSTRACT

Core and ditch cutting of shaly samples were selected from 5 wells within the Orange Basin, South Africa. It was with a view to studying the palynological contents of the samples and to also delineate the environment and condition in which the samples were formed. The samples were prepared for palynological studies using standard extraction techniques involving HCL, HF treatments, wet sieving with 10 µm polyester sieve and mounting of samples on glass slides using glycerine jelly. The samples were moderately abundant and diversified in pollen and spores. Sixty-eight palynomorphs species were identified and were used for biozonation. Two biozones were identified in this study. These were SI in Wells A_C2, A_U1 and top of Well O_A1 and SII in Wells K_BI, A_F1 and base of Well O_A1. The SI with interval between 2030 m and 4170 m was characterized by acme of *Inaperturopollenites sp* at 2697 m in Well O_A1. Other palynomorphs identified within the zone were *Anglatisporites sp, Triporites sp* and *Polypodiaceoisporites retirugutus* with age range of possibly between Valanghian-Barremian. The SII zone at interval of between 1330 m and 2030 m and with age range of Aptian to Albian at the base was defined by *Antulsporites baculatus* at 2030 m at the top of Well A_O1. This zone was further characterized by the occurrence of *Klukisporites sp* and *Taurocusporites sp* at depths of 1330 m and 1690 m in Well A_F1, respectively. The few counts of *Bacutriporites sp*, *Classopollis sp*, *Polyangulatisporites sp* were also recorded within the zone. The palynoflora assemblages were quantitatively dominated by brackish to fresh water swamp species such as *Laevigatosporites sp, Polypodiaceoisporites sp* with moderate counts of forest species such as *Saptaceoideapollenite sp.* The environment of deposition of the sediments was brackish to fresh water.

Keywords: Palynology, Paleoenvironment, Biozonation, Orange Basin, Palynoflora

INTRODUCTION

Palynology has contributed greatly to our understanding of early angiosperm diversification in the Cretaceous. The presence of palynomorphs in the continental and marine environments makes them a veritable tool in cross-correlation of the marine and non-marine sedimentary succession. A lot has been documented about the breaking down of the supercontinent- the Gondwana during the Phanerozoic time which was responsible for where the continents are at present time. Researchers have also documented evidences of pre-rift, syn-rift and post-rift occurrences in the Orange Basin as part of oil exploration protocols (van Der Spuy, 2003; Hirsch et al., 2009; Hirsch et al., 2010).

Sandersen *et al.* (2011) worked on the biozonation based on terrestrial palynomorphs from two wells in the offshore Orange Basin of South Africa. They were able to establish five palynological zones from each of the two wells. They found out that the Early Cretaceous intervals in the wells showed considerable degree of similarity in palynological records; indicating that the terrestrial plant communities were relatively uniform. The identical terrestrial palynoflora include 41 species of angiosperm and gymnosperm pollens, 85 species of fern and bryophyte spores and two monolete spore taxa. They also concluded that the Late Cretaceous interval however showed marked differences suggesting that the plant communities had become more diverse and that the palynomorphs were being supplied from separate geographical areas. There are other publications on the palynological studies of the Orange Basin. Martin (1960); Scott (1976); Scholtz (1985); De Villiers and Cadman (1997, 2001); Oboh-Kuenobe and De Villiers (2003) worked on the onshore deposits of the basin while McLachlan and Pieterse (1978); Zavada and Benson (1987); Brown *et al.* (1996) and Zavada (2004) studied the offshore areas. Palynological studies have been a very useful tool in the determination of both oil and gas reservoirs and potential source rocks (Franca and Potter, 1988).

This research work intends to outline the trends in palaeobotany during the Cretaceous period and provides a background to the type of vegetation expected of the Orange Basin during the period. It also aimed at the identification of the various taxa of palynomorphs present in the studied area, systematic description of palynomorph assemblages, analysis of the palynomorphs with respect to age determination, determination of the depositional environment of the formation, palynostratigraphic zonation of the studied area and paleoenvironmental reconstructions.

The study Area

The Orange Basin, offshore Southwest Africa, is located within the passive continental margin of the South Atlantic between Latitudes 31° and 33.5 °S (Akinlua *et al*., 2011) (Fig. 1). The offshore Orange Basin extends to approximately 50 km between Cape Town and the Namibian border with South Africa.

Geological Setting

The basin was developed within a divergent plate boundary setting in response to lithospheric extension related to the break-up of South America and Africa in the Late Jurassic, followed by seafloor spreading and the opening of the South Atlantic Ocean in the Early Cretaceous, around 136 Ma (Brown *et al.,* 1996; Reeves and de Wit, 2000; Macdonald *et al*., 2003). The latest models of the relative motion between the South American and the African plates suggest a diachronous opening of the South Atlantic, starting in the south and propagating to the north within a time span of 40 Ma (Eagles, 2007). The Orange Basin contains the stratigraphic record from lithospheric extension and rift tectonics throughout a fully evolved post-break-up setting, and thus provides an ideal area to study the evolution of a "passive" continental margin (Hirsch et al., 2009). The stratigraphy comprises a pre-rift

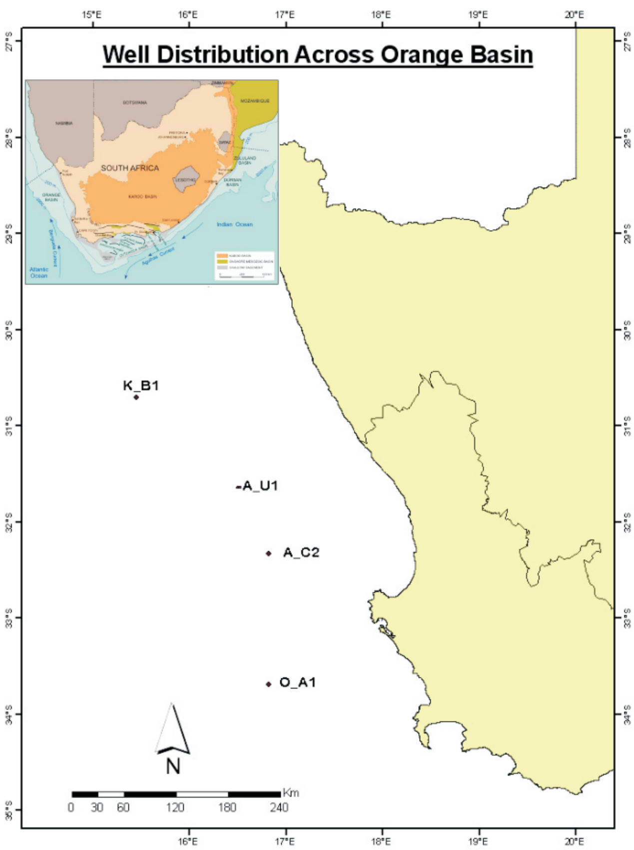

Fig. 1. Map Showing Location of the Wells in Orange Basin, South Africa. (Insert is the Location of the Basin Southwestern part of South Africa Republic).

successions (older than Late Jurassic, >~130 Ma), that is overlain by syn-rift deposits of Late Jurassic to Hauterivian age (~121 to~117.5 Ma), and, in turn, by sediments of early drift stages up to Aptian age (~113 to ~108 Ma) (Fig. 2). Non-restricted marine deposits of an Aptian age overly the Pre-Aptian successions (Jungslager, 1999). The rift stage basin was characterized by the development of north to south oriented grabens and half-grabens trending approximately parallel to the rift axis, from near Walvis Bay to south of Cape Town (Gerrard and Smith, 1982). These graben structures were filled predominantly with siliciclastic continental and lacustrine rocks, and variable thicknesses of volcanic rocks (Brown *et al.*, 1996). The syn-rift fill, which is

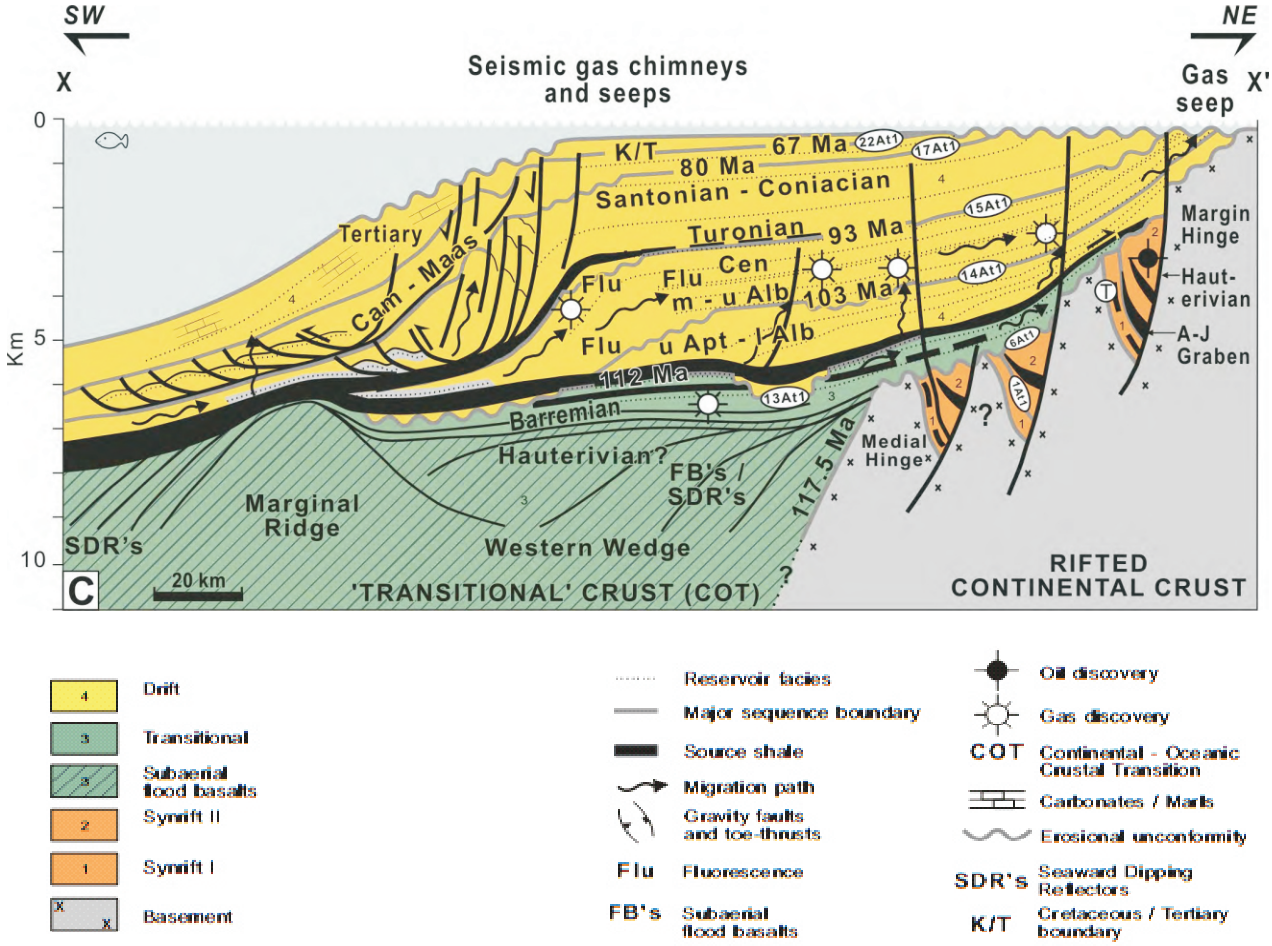

Fig. 2. Illustration of a Generalized Composite Stratigraphic Cross-section through the Orange Basin as Proposed by Jungslager (1999).

Upper Jurassic and Lower Cretaceous in age sequences rest unconformably on the Precambrian or Paleozoic basement and are unconformably overlain by Early Cretaceous to present post-rift successions. Lithologically, the early post-rift successions comprise sandstone and shales, and the majority of the post-rift successions are claystones. Most of the syn-rift sequences were deposited immediately to the east of the marginal ridge and within isolated half-grabens on the middle and inner shelf. The post-rift sequence has a greater than 7 km thick post-rift Barremian/Lower Aptian to present day interval that thins to an approximately 3 km thick sequence in the study area in the south (Gerrard and Smith, 1982). The Barremian/Lower Aptian sequence corresponds to a transitional phase between syn-rift and drift during which time period the highest quality source rock was deposited. This sequence is overlain by more than 5500 m of Upper Cretaceous shales and claystones that are relatively undeformed. The overlying Cenozoic strata were deposited basin-ward of the Cretaceous sequence with a thickness of greater than 1500 m towards the outer margin (Gerrard and Smith, 1982).

MATERIALS AND METHODS

25 core and ditch cuttings shale samples from 5 wells between 1330-4170 m were processed and analysed for their palynomorphs content using standard extraction techniques involving HCl, and HF treatments, wet sieving with 10 μm polyester sieve and mounting on glass slides using glycerine jelly. Two slides per samples were studied under the microscope and numerical abundance of the palynomorphs recorded using a light transmitted Olympus CX41 microscope of magnification x25 and x40. Photographs of the palynomorphs were taken using the attached Olympus DP 12 digital camera. The recorded palynomorphs on the log analysis sheet were transferred into the computer for chatting using Stratabug biostratigraphic software.

RESULTS AND DISCUSSION

The results of the analyses showed that the samples were moderately abundant and diversified in pollen and spores. Sixty-eighty (68) palynomorph species were identified and used for the biozonation and interpretation of the well (Table 1, see the Appendix). Two biozones were recognized and named Zones SI (Figs. 3, 4 and 5) and SII (Figs. 5, 6 and 7). Zone SI had interval of between 2030 m and 4170 m and age range of between Valanghian (Fig. 5) and Barremian to Aptian (Figs. 3 and 4). The base of this zone was not recognized as it on stratigraphically deeper than the last sample analysed. The zone is characterized by the acme of *Inaperturopollenites sp* at 2697.55 m (Fig. 5). Other palynomorphs identified within the zone were *Cingulatisporites sp, Triporites sp* and *Polydiaceoisporites retrigutus* (Figs. 3, 4 and 5).

Zone SII had age range of between Aptian and Albian (Figs. 5, 6 and 7). The top of this zone was not encountered as it was stratigraphically higher than the first sample analysed. The base was defined by the top occurrence of *Antulsporites baculatus* at 2030.35 m (Fig. 7, Plate 1).

The zone was further characterized by the occurrence of *klukisporites sp* and *Taurocusporites* sp. at 1330.40 m and 1690.00 m (Fig. 6) respectively. Few counts of *Bacutriporites sp, Classopollis sp, Polycingulatisporites sp* and *Polydiaceoisporites sp* were also recorded within the zone (Figs. 5, 6 and 7).

Palynological Distributions in the Wells Studied

WELL A_U1: Interval 2688.10 – 3245.39 m (Fig. 3)

This interval is characterized by *Apiculatisporite sp*, *Inaperturopollenites sp*., *Distaltriangulatisporites cf. maximus, Ornamentifera sp., Distaverrusporites sp*., and dinocysts species such as *Senegalinium sp.,* and *Leoisphaeridia sp*., *Cleistosphaeridium sp.* The occurrences of other Early Cretaceous species such as *Taurocusporites segmentatus, Pterospermopsis sp*., were also recorded. This assemblage suggests Barremian to Aptian age for this interval.
The occurrence of *Deltoidospora* indicates the presence of pteridophytes. The pteridophyte sporomorphs: *Cyathides sp, Gleicheniidites* and the gymnosperm pollen *Classopollis, Auracariacite sp, Monosulcites* and undetermined inaperturate pollen *Inaperturopollenites sp.* were recorded from this well also. Gymnosperm pollen *Ephedripites sp,* had its first occurrence.

WELL A_C2: Interval 3244.20-3245.52 m (Fig. 4)

The occurrence of *Araucariacites australis, Inaperturopollenites sp* characterized the interval 3244.20-3245.52 m (ditch cutting samples) suggesting Barremian to Aptian age. The occurrence of diatom frustule which is a salt water diatom skeleton found in aquatic environment was recorded at depth 3245.52 m indicating ocean incursion.

The interval 3244.53-3246.32 m (core samples) was poor in palynomorph recovery with rare occurrence of *Antulsporites baculatus* at depths 3245.16 m and 3246.70 m. This probably suggests Early Cretaceous (Barremian) age. At depth 3244.53 m and 3244.84 m, there were occurrence of charred graminae cuticle.

WELL O_A1: Interval 1463-4171 m (Fig. 5)

This interval recorded species such as *Pterospermopsis sp, Glecheniidites sp, Polypodiaceoisporites retirugatus* and *Antulsporites cf. baculatus* which suggest Aptian to Albian age. Occurrence of graminae cuticle was recorded in this well also.

WELL A_F1: Interval 1330-1790 m (Fig. 6)

This interval was characterized by palynomorphs such as *Trilobosporites sp., Cicatricosisporites cf. orbiculatus, Klukisporites sp., Cicatricosisporites augustus* amongst others. The admixture probably suggests Aptian to Albian age. Occurrence of diatom frustules was also recorded.

WELL K_BI: Interval 1845.80-2030.35 m (Fig. 7)

This interval was characterized by the occurrence of Early Cretaceous species such as *Striatopollis cf. crassimuratus, Antulsporites baculatus, verrucasisporites rotundus, Pterospermopsis sp., Polycingulatisporites sp., Taurocusporites segmentatus* amongst other species which suggest an Aptian to Albian age.

The pteridophyte sporomorphs characterizing the Early Cretaceous time were recorded and represented mainly by *Cyathidites sp, Gleicheniidites* in all the wells studied (Figs. 3 to 7). Gymnosperm pollen of the class genera *Classopollis, Aruacariacite sp, Monosulcite* were recorded in nearly all the wells (Figs. 3 to 7). Also undetermined inaperturate pollen *Inaperturopollenites* sp. and Angiospermous pollen were dominated by palms *Monosulcites* sp in nearly all the wells studied (Figs. 3 to 7).

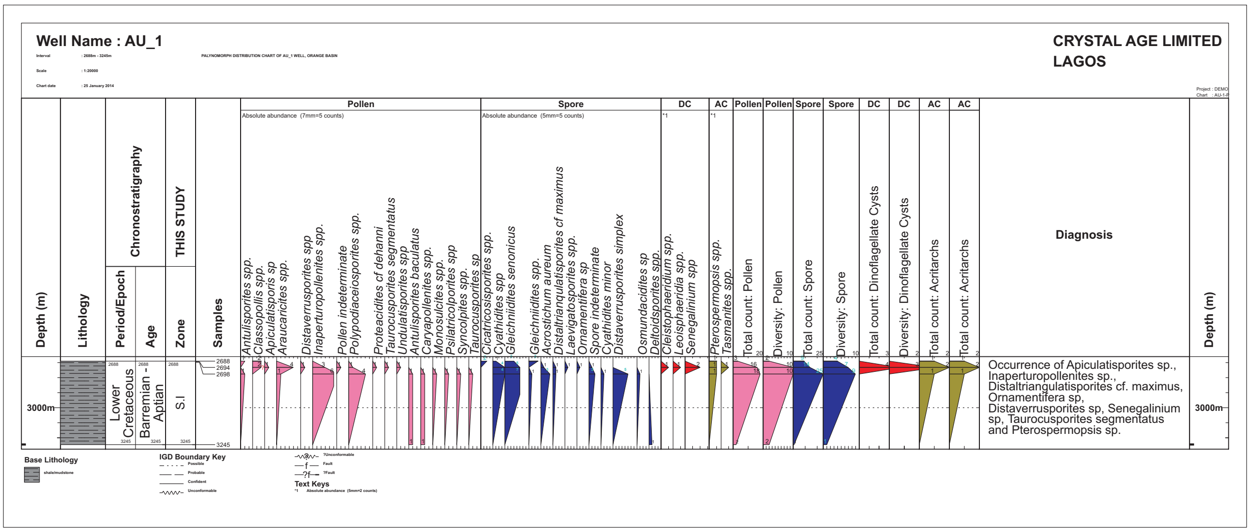

Fig. 3. The Palynomorph Distributions Chart of the Well A_U1 of Orange Basin. (The Chart shows the Ages of the Recovered Palynomorphs and the Index Palynomorphs which Marked the Zones as Recorded in the Diagnosis Section of the Chart).

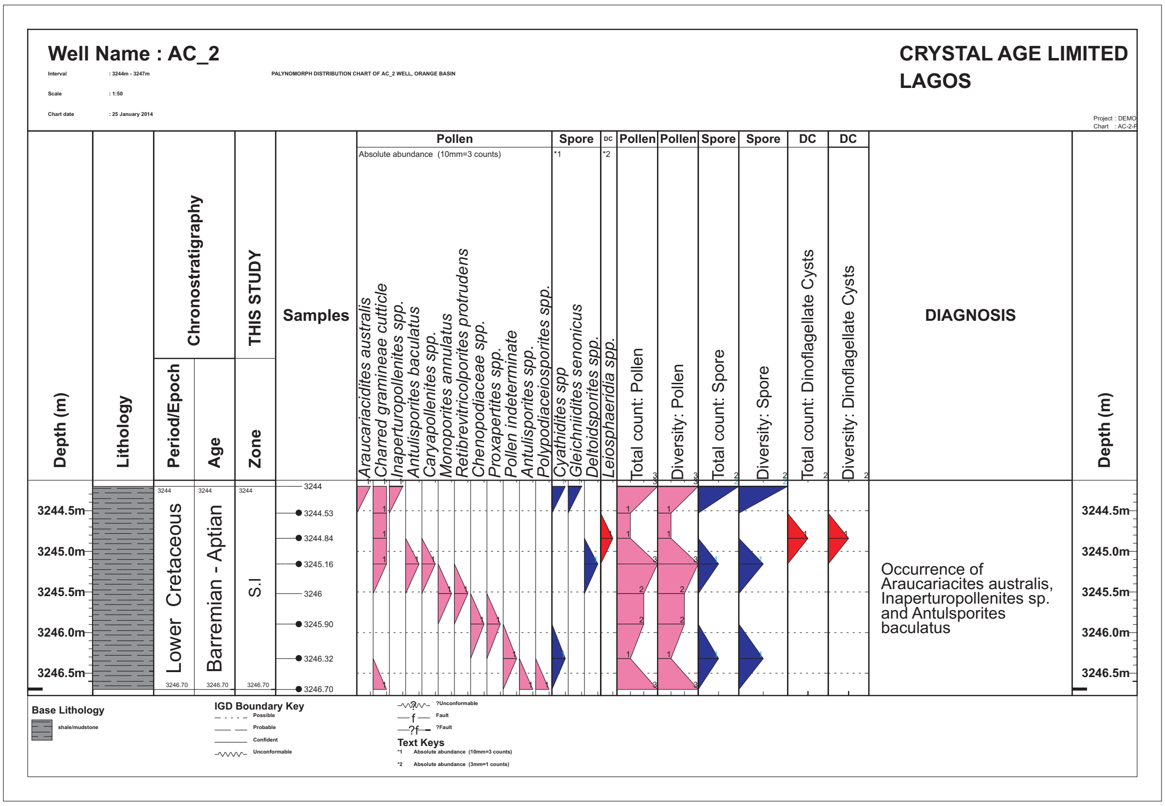

Fig. 4. The Palynomorph Distributions Chart of the Well A_C2 of Orange Basin. (The Chart shows the Ages of the Recovered Palynomorphs and the Index Palynomorphs which Marked the Zones as Recorded in the Diagnosis Section of the Chart)

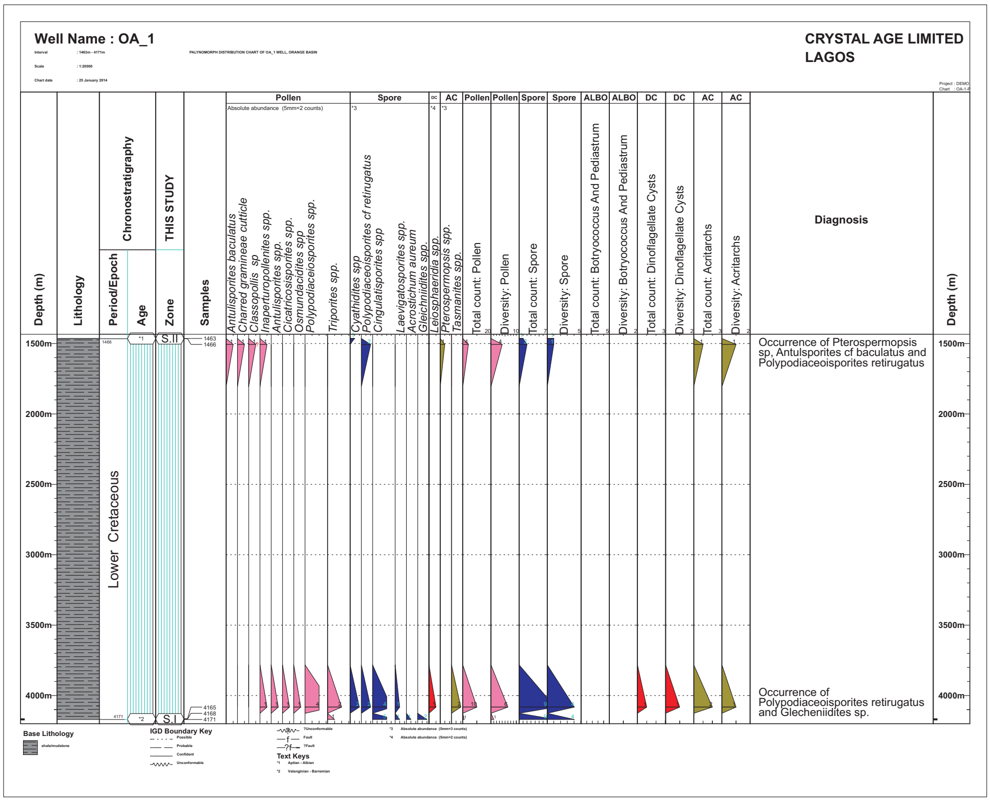

Fig. 5. The Palynomorph Distributions Chart of the Well O_A1 of Orange Basin. (The Chart shows the Ages of the Recovered Palynomorphs and the Index Palynomorphs which Marked the Zones as Recorded in the Diagnosis Section of the Chart).

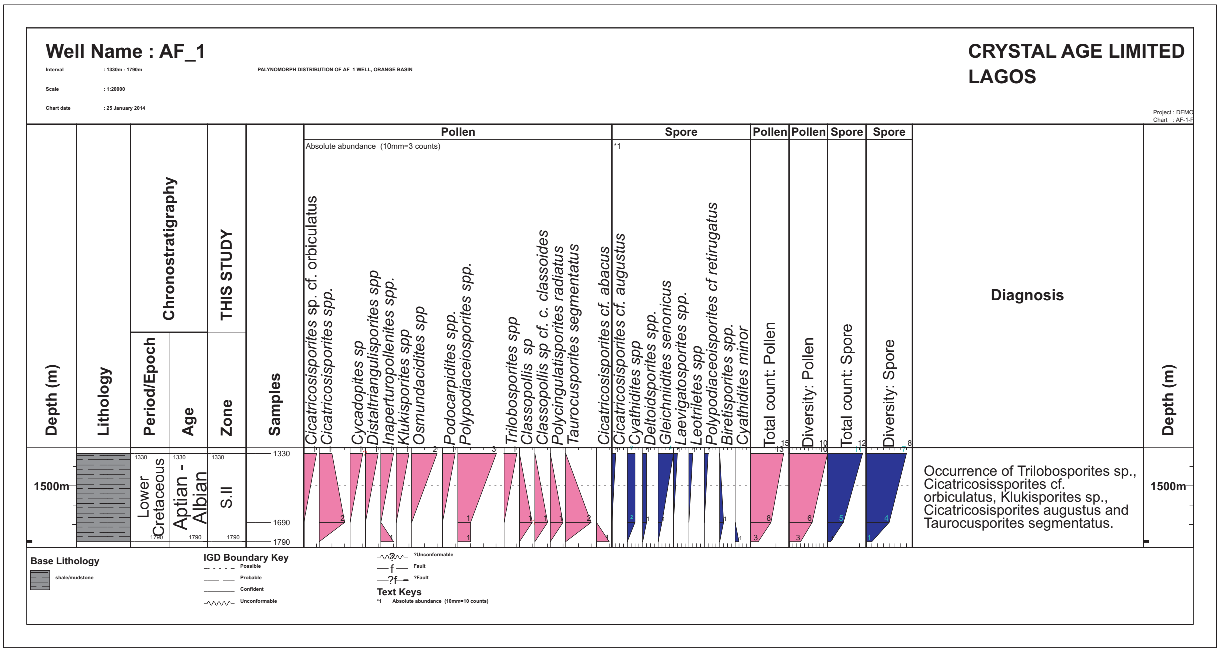

Fig. 6. The Palynomorph Distributions Chart of the Well A_F1 of Orange Basin. (The Chart shows the Ages of the Recovered Palynomorphs and the Index Palynomorphs which Marked the Zones as Recorded in the Diagnosis Section of the Chart).

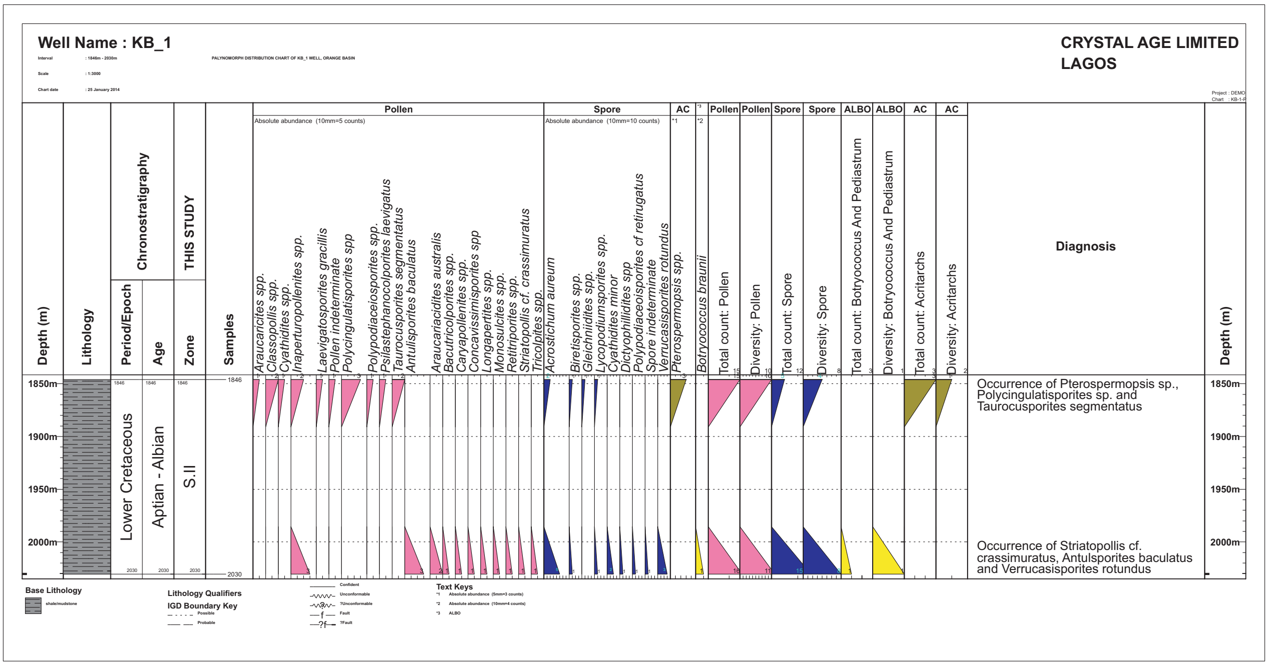

Fig. 7. The Palynomorph Distributions Chart of the Well K_B1 of Orange Basin. (The Chart shows the Ages of the Recovered Palynomorphs and the Index Palynomorphs which Marked the Zones as Recorded in the Diagnosis Section of the Chart).

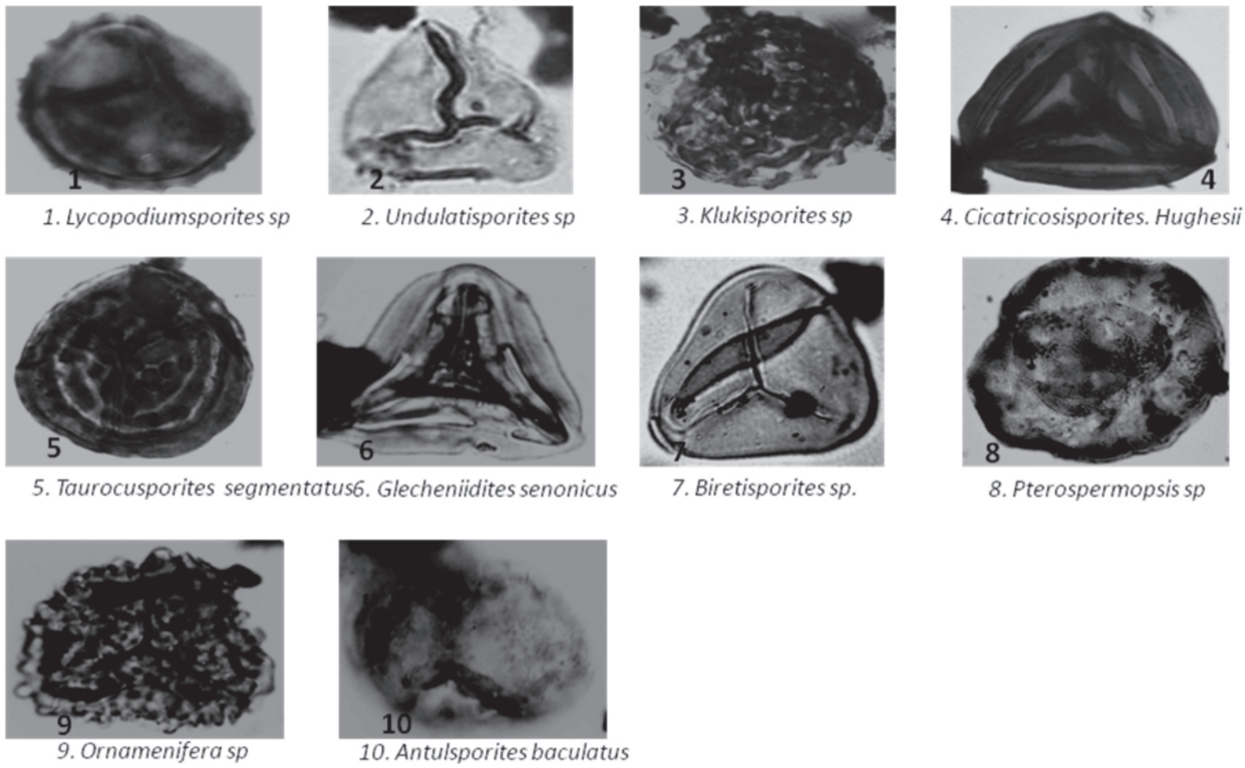

Plate 1. The Photographs of Major Species of Palynomorphs Recovered from Orange Basin. (These Key Palynomorph Species are used in the Diagnosis of Palynomorph Assemblages).

Age Determination

On the basis of palynomorph assemblages, it was observed that the analyzed wells of the Orange Basin are of Cretaceous age having palynomorph distribution between the Lower and Upper Cretaceous (Figs. 3 to 7).

Paleoenvironmental Determination

The palynofloral assemblage was quantitatively dominated by brackish to fresh water swamp species such as *Laevigatosporites sp* with moderate counts of forest species such as *Sapotaceoidaepollenites sp* (see Appendix).

Paleoecological and paleoclimatical considerations were mainly based on changes in the bulk composition of palynoflora and the botanical affinities of selected palynomorphs. The relative frequency of some spores, mainly *Deltoidospora* indicates presence of pteridophytes. Gymnosperms are mostly represented by number of undetermined inaperturate pollen (*Inaperturopollenites* sp.) Angiospermous pollen is dominated by palms (*Monosulcites* sp.) (Fig. 3). The gymnosperm pollen *Ephedripites sp.,* and *Classopollis sp* (Figs. 3 to 7) were also recognized. The Angiosperms were rare.

CONCLUSION

Two depositional environments were identified. One is rich in small marine neritic organic matter dominated by neritic marine dinoflagellates cysts and freshwater algae suggesting strong terrestrial influence. The other, near shore is rich in large particles of organic matter with relative explosion of terrestrial spores and pollen grains. The poor preservation of dinocysts along the interval was interpreted as related to physical and chemical conditions which prevailed in the depositional settings during a probable drop in sea level that caused a decrease in the water column and induced turbulence. The presence of calcareous dinoflagellates assemblages indicates a relatively warmer climate during the Early Cretaceous (Fig. 4 and 5) and a colder one during the Upper part whereas pollen of palms suggests tropical humid climate. Ferns and mosses occur in greater abundance than the conifers and angiosperms combined. The most prevalent fern and moss species are *Cicatricosisporites sp*, and *Taurocusporites sp*

(Fig. 3).

Fresh water green algae are present, suggesting that an environment of terrestrial lakes occurred not far from the palynodebris accumulation zones. The presence of microphytoplanktons in some samples is an indication of mixture of freshwater elements with the marine elements or an indication of near shore facies during the deposition or sedimentation time. The microfloras show that the paleoenvironments was favourable for different kind of plants with high percentage of the pteridophytes sporomorphs, followed by angiosperms and gymnosperms. These indicate that the terrestrial wet land and regression were most common at that time. The abundance of pollen flora is an indication that the shoreline is of lagoon or brackish water and that they are dominant.

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Taxonomic List

GENUS: *Laevigatosporites* (Bennie and Kidston) (Potonie, 1956)

DESCRIPTION: Medium sized spore, smooth, ellipticalto planoconvex monolete spore. Exine is psilate with prominent monolete mark

REMARK: Specimens of this species are abundant and have variable sizes (small and fairly big specimens)

GENUS:*Cicatricosisporite* (Potonie and Kremp, 1954)

DESCRIPTION: Triangular to subtriangular, trilete spore,heteropolar, rounded distal poles and pointed proximal poles. Surface is cicatricose with diagnostic prominent striae. Trilete marks are short, absent or not prominent.

REMARKS: Most of the specimens recovered are poorly preserved they are abundant in

GENUS: *Polydiaceiosporites* (Potonie, 1956)

DESCRIPTION: Spore with trilete mark,triangular in equitorial view. Trielte mark is thin, long, narrow and not too conspicous. Exine is thick and has indistinct sculpture.

REMARKS: Variation occurs in the sizes of the spores. Some grains are with roundeed corners while othersnhave airly rounded edge.

GENUS: *Retimonocolpites* (Pierce, 1961)

DESCRIPTION: Pollen grain of medium size,anisopolar, bilaterrally symmetrical, monosulcate. The exine is thick and its sculpture varies from very finely retculate to vermiculate.

REMARK: The sulcus shape and the size of the grain are very variable.

GENUS: *Gleicheiniidites* (Ross, 1949; Skarby, 1978)

DESCRIPTION: Triangular trilete miospore, sides fairly convex, trilete mark distinct, extend almost to the radial corner of the spore, exine thin.

REMARKS: They have a fairly high abundance in the studied samples of Section A.

GENUS: *Cingulatisporite*s (Thomson and Pflug, 1953)

Cingulatisporites ornatus (van Hoeken-Klinkenberg, 1964)

DESCRIPTION: Sub-triangular pollen, cingulated, Cingulum of uniform diameter, margin crenulate, radial corner round, trilete mark distinct, distal surface has irregular structural elements, exine is thin, ectexine and endexine layer not very distinct.

REMARKS: Occur initially at the boundary between Campanian and Maastrichtian.

GENUS: *Ephedripites* (Bolkovitina) (Potonie, 1958)

Ephedripites sp (Herngreen, 1973)

DESCRIPTION: Elliptical pollen, moderate, prolate, a number of rib run from one pole to the other, and protrude in outline i.e. Costate, rib fuse at the poles, surface of costate smooth, exine thin, extexine and endexine layer not recognizable.

REMARKS: Very rare in both of the intervals studied.

GENUS: *Tricolporopollenites* (Thomson and Pflug, 1953)

Tricolporopollenites sp (Potonie, 1958).

DESCRIPTION: Small elliptical pollen, polar axis longer than equatorial axis, prolate, colpi distinct with each, having equatorial type, outline smooth, exine thin.

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APPENDIX

Table 1. The Distribution of Palynomorph Species with Numbers Counted for Specie Types in the Wells Studied.

WELL Depth (m)	**SPECIES**	**COUNTS/ SPECIES TYPE**	**REMARK**
KB_1			This interval (**1845.80 - 2030.35m**) is characterized by occurrence of Early Cretaceous species such as *Striatopollis cf. crassimuratus, Antulsporites baculatus, verrucasisporites rotundus, Pterospermopsis sp., Polycingulatisporites sp., Tauro cusporites segmentatus* amongst other species which suggest an Aptian to Albian age.
2030.35	*Striatopollis cf. crassimuratus.*	1 P	
	Araucariacites australis	2 P	
	Acrostichum aurem	5 S	
	Botryococcus braunii	1 FWA	
	Inaperturopollenites sp	3 P	
	Monosulcites sp1	1 P	
	Antulsporites baculatus	3 S	
	Biretisporites sp	1 S	
	Longapertites sp	1 P	
	Cyathidites minor	2 S	
	Polypodiaceoisporites cf. retirugatus	1 S	
	Tricolpites sp	1 P	
	Concavissimisporites sp.	1 S	
	Verrucasisporites rotundus	3 S	
	Bacutricolpites sp	1 P	
	Retitricolpites sp	1 P	
	Spore indeterminate	1 S	
	Dictyophyllidites sp	1 S	
	Lycopodiumsporites sp.	1 S	
	Caryopollenites sp	1 S	

WELL Depth (m)	**SPECIES**	**COUNTS/ SPECIES TYPE**	**REMARK**
1845.80			
	Pterospermopsis sp.	3 P	
	Polycingulatisporites sp.	3 S	
	Lycopodiumsporites sp.	1 S	
	Classopollis sp.	2 P	
	Inaperturopollenites sp	2 P	
	Acrostichum aureum	2 S	
	Psilstephanocolporites laevigatus	1 P	
	Cyathidites sp.	1 S	
	Taurocusporites segmentatus	2 S	
	Biretisporites sp.	1 S	
	Araucariacites sp.	1 P	
	Pollen indeterminate	1 P	
	Glecheniidites sp.	1 S	
	Laevigatosporites gracillis	1 S	
	Polypodiaceoisporites sp.	1 S	
AU_1			This interval (**2688.10 – 3245.39m**) is characterized by *Apiculatisporitessp*, *Inaperturopollenitessp*., *Distaltriangulatisporites cf. maximus, ornamentifera sp.,* *Distaverrusporites sp*., and dinocysts species such as *Senegalinium sp.,* and *Leoisphaeridia sp*., *Cleistosphaeridiumsp* occurrence of other Early Cretaceous species such as *Taurocusporites segmentatus, Pterospermopsissp*., are also recorded. This assemblage suggest Barremian to Aptian age for this interval
2688.10	*Glecheniidites senonicus*	3 S	
	Classopollis sp.	2 P	
	Cyathidites sp	1 S	
	Cicatricosisporites sp.	2 S	
	Antulsporites sp		
	Antulsporites sp.	1 S	
	Pterospermopsis sp.	1 S	
2694.05	*Cyathidites sp*	4 S	
	Taurocusporites segmentatus	1 S	
	Apiculatispories sp	1 S	
	Pollen indeterminate	1 P	
	Polypodiaceoisporites sp	1 S	
	Inaperturopollenites sp	3 P	
	Senegalinium sp	2 DC	
	Pterospermopsis sp	1 S	
	Proteacidites cf. dehanni	1 P	
	Araucaricites sp.	4 P	
	Glecheniidites senonicus	5 S	

WELL Depth (m)	**SPECIES**	**COUNTS/ SPECIES TYPE**	**REMARK**
	(?) Classopollis sp	2 P	
	Cleistosphaeridium sp.	1 DC	
	Laevigatosporites sp.	1 S	
	Leoisphaeridia sp.	1 DC	
	Distaltriangulatisporites cf. maximus	1 S	
	Tasmanites sp.	1 DC	
	Acrostichum aureum	1 S	
	Ornamentifera sp.	1 S	
	Undulatisporites sp.	1 P	
	Distaverrusporites sp.	1 S	
	Spore indeterminate	1 S	
2697.55			
	Cyathidites sp	4 S	
	Polypodiaceoisporites sp	4 S	
	Glecheniidites senonicus	7 S	
	Inaperturopollenites sp	6 P	
	(?) Distaltriangulatisporites maximus	1 S	
	Taurocusporites sp	1 S	
	Distaverrusporites simplex	5 S	
	Antulsporites sp.	1 S	
	Spore indeterminate	2 S	
	Acrostichum aureum	3 S	
	Psilatricolporites sp.	1 P	
	Araucariacites australis	1 P	
	Syncolpites sp	1 P	
	Monosulcites sp	1 P	
	Pterospermopsis sp.	1 S	
	Glecheniidites sp	1 S	
	Osmundacidites sp	1 S	
	Caryopollenites sp	1 P	
	Ephedripites sp	1 P	
	Polycingulatisporites cf. reduncus	1 S	
	Cyathidites minor	1 S	
3245.39	*Caryopollenites sp*	1 P	
	Antulsporites baculatus	1 S	
	Deltoidosporites sp	1 S	
AC_2			The occurrence of Araucariacites australis, Inaperturopollenites sp characterizes this interval (**3244.20-3245.52m**) suggesting (?) Barremian to Aptian age.
3244.20	*Araucariacites cf. australis*	1 P	
	Glecheniidites senonicus	1 S	
	Inaperturopollenites sp	1 P	
	Cyathidites sp	1 S	
	Charred Graminae cuticles	1	
3245.52	*Monoporites annulatus*	1 P	
	Retibrevitricolporites protrudens	1 P	
	Diatom frustule	1	

WELL Depth (m)	SPECIES	COUNTS/ SPECIES TYPE	REMARK
AC_2*1 (Core samples)			This interval (**3244.53-3246.32m**) poor in palynomorph recovery with rare occurrence of *Antulsporitesbaculatus* occurring at 3245.16m and 3246.70m. This probably suggests Early Cretaceous (Barremian) age.
3244.53	*Charred Graminae cuticle*	1	
3244.84	*Charred Graminae cuticle*	1	
	Leoisphaeridia sp.	1 DC	
3245.90	*Chenopodiaceae sp*	1 P	
	Proxapertites sp	1 P	
3245.16	*Charred Graminae cuticle*	1	
	Deltoidosporites sp	1 S	
	Antulsporites baculatus	1 S	
	Caryopollenites sp	1 P	
3246.70	*Charred Graminae cuticle*	1	
	Polypodiaceoisporites sp	1 S	
	Antulsporites sp	1 S	
3246.32	*Cyathidites sp*	1 S	
	Pollen indeterminate	1 P	
AF_1			This interval (**1330-1790m**) is characterized by palynomorphs such as *Trilobosporites sp., Cicatricosisporites cf. orbiculatus, Klukisporites sp., Cicatricosisporites augustus* amongst others. The admixture probably suggests Aptian to Albian age.
1330.40	*Osmundacidites sp*	2 S	
	Trilobosporites sp	1 S	
	Cyathidites sp	2 S	
	Deltoidosporites sp	1 S	
	(?) Cycadopites sp	1 P	
	Cicatricosisporites sp. cf. orbiculatus	1 S	
	Glecheniidites senonicus	4 S	
	Leotriletes sp	1 S	
	Cicatricosisporites sp	1 S	
	Laevigatosporites sp	1 S	
	Podocarpidites sp	1 P	
	Polypodiaceoisporites sp	3 S	
	Distaltriangulatisporites sp	1 S	
	Klukisporites sp	1 S	
	Cicatricosisporites cf augustus	1 S	
	Inaperturopollenites sp	1 P	
	Polypodiaceoisporites retirugatus	1 S	
1690	*Polypodiaceoisporites sp*	1 S	
	Cicatricosisporites sp	2 S	
	Classopollis sp cf. C. classoides	1 P	
	Deltoidosporites sp	1 S	

WELL Depth (m)	SPECIES	COUNTS/ SPECIES TYPE		REMARK
	Gleicheniidites senonicus	1	S	
	Taurocusporites segmentatus	2	S	
	(?) Classopollis sp	1	P	
	Polycingulatisporites radiatus	1	S	
	Cyathidites sp	2	S	
	Biretisporites sp	1	S	
1790	*Diatom frustules*	2		
	Cyathidites minor	1	S	
	Polypodiaceoisporites sp	1	S	
	Inaperturopollenites sp	1	P	
	Cicatricosisporites cf. abacus	1	S	
OA_1				This interval (**1463.43 - 6166.75m**) records species such as *Pterospermopsissp*., *Gleicheniiditessp*., *Polypodiaceoisporitesretirugatus* and *Antulsporitescf. baculatus* which suggest Aptian to Albian age.
1463.43	*Cyathidites sp*	1	S	
1465.59	*(?) Classopollis sp*	1	P	
	Pterospermopsis sp	1	S	
	Charred Graminae cuticle	1		
	Polypodiaceoisporites retirugatus	2	S	
	Inaperturopollenites sp	1	P	
	Antulsporites cf. baculatus	1	S	
4164.56	Inaperturopollenites sp	1	P	
	Osmundacidites sp	1	S	
	Polypodiaceoisporites retirugatus	2	S	
	Polypodiaceoisporites sp	4	S	
	Triporites sp	2	P	
	Antulsporites sp	1	S	
	Cicatricosisporites sp	1	S	
	Cingulatisporites sp	4	S	
	Cyathidites sp	2	S	
	Laevigatosporites sp	1	S	
	Tasmanites sp	2		
	Leoisphaeridia sp	1	DC	
4168.45	Fungal spore	1	S	
4170.53	Triporites sp	1	P	
	Acrostichum aureum	1	S	
	Cingulatisporites sp	5	S	
	Gleicheniidites sp	2	S	
	Laevigatosporites sp	1	S	

PLEASE NOTE:

- P=POLLEN
- S=SPORE
- DC= DINOFLAGELLATE CYSTS
- FWA= FRESH WATER ALGAE.