Revision of the Cretaceous Sundays River Type Formation, with Palynomorph Assemblages Onshore Algoa Basin, South Africa, Preliminary Results

*Simamkele Jamjam [1], Jacques Durand [1], Ndubuisi Ukpabi [2], Tapus Chatterjee [1] and Mimonitu Opuwari [1]
[1]University of the Western Cape Geo-Xnt
[2]Centre for Petroleum Geosciences (CPG), University of Port Harcourt

ABSTRACT

The Algoa Basin, located along the southeastern margin of South Africa, is one of the several Mesozoic sedimentary rift basins (together known as the Outeniqua Basin) and is subdivided into three half grabens. The Cretaceous series (Uitenhage Group) is particularly well represented in this basin, with some of the most important sections in this region. However, the paucity of geochemical biomarker fingerprinting data in this relatively underexplored area has led to a poor understanding of the area's stratigraphy, as biostratigraphy can give important information about age and deposition. This study aims to review the Cretaceous Sundays River Type formation by assessing and characterizing biostratigraphical data considering all the palynomorph assemblages, and assessing stratigraphical features in the type section. Cretaceous successions exposed at farms south of Addo, Amsterdamhoek and road cut sections near Kirkwood in the Onshore Algoa Basin were analyzed for palynological studies and in this study only the Type section results are presented. The palynological preparation technique followed the standard mineral acid digestion method. Palynomorphs identified in the study indicated Valanginian to Hauterivian Cretaceous age. This provided biostratigraphic and paleoenvironmental data source for critical review of the stratigraphic framework of Sundays River Formation, which is recognized as the primary potential source rock and reservoir of the Cretaceous Petroleum System of Outeniqua Basin.

Keywords: Biomarkers, Biostratigraphy, Palynomorph, Cretaceous, Quteniqua Basin, Grabens, Mesozoic.

INTRODUCTION

Lower-Createceous source rocks in the Outeniqua Basin, in which the Algoa Basin is are known to be oil and gas prone with all the synrift source rocks mature over large parts of the area. Hydrocarbon prospectivity is rated high in this area, containing almost all of South Africa's proven hydrocarbons. However, since McLachlan and McMillan's work no palaeontological work has been done in this basin. Paucity of geochemical biomarker fingerprinting data in this relatively poorly explored area (Jungslager, 1999) has lead to a poor understanding of the stratigraphy of the area as biostratigraphy can give very important information about deposition. The seqeunce-stratigraphic approach has widespread application in petroleum exploration and has relevance for understanding and predicting the occurrence of petroleum source rock and resevoirs. Resultantly, detailed palynological studies arerequired for the understanding of the geological history of this terrain. Palynofloral studies are effectively used in stratigraphy to determine the chronology of the sedimentation and to correlate continental as well as marine sections from varying localities and lithologies. The aim of this thesis is to review the cretaceous type formations of the Outeniqua Basin using all the necessary available data. The objectives of this study are to: (1) Review the existing knowledge in Stratigraphy and Biostratigraphy of the cretaceous type formations of the Southern basins. (2) Assess and characterize biostratigraphical data considering all the palynomorphs. (3) Assess stratigraphical features in the type section.

GEOLOGICAL SETTING

The study area for this project is the Algoa Basin, located along the southeastern margin of South Africa (fig.1). It is one of several Mesozoic sedimentary rift basins and is

The authors wish to thank the University of the Western Cape Geo-Xnt, Centre for Petroleum Geosciences (CPG), University of Port Harcourt and NAPE for providing the platform to present the paper during the Annual Conference.

subdivided into three half grabens, the offshore Port Elizabeth and Uitenhage troughs and the onshore Sundays River Trough (Fig 2).

The late Mesozoic sediments in the Southern Cape province are confined in the Outeniqua Basin (Dingle and Scrutton, 1974), also previously known as the Agulhas Basin (Simpson and Dingle, 1973) or St Francis Basin (Emery *et al,* 1975), which lies between the Agulhas and Port Alfred arches and subdivided by smaller block-faulted buried ridges (Dingle, 1973). These basement arches comprise of Ordovician to Devonian metasediments of the Cape Supergroup and the arcuate trend of the basin-bounding fault systems is most likely inherited from the structural grain of the underlying orogenic Cape Fold belt

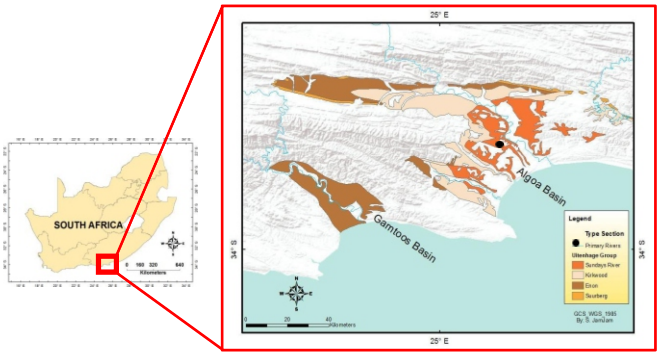

Figure 1: Location map showing the extent of the Uitenhage Group in the Algoa and Gamtoos basins.

(De Swardt and McLachlan, 1982). The Outeniqua Basin shows a history of strong

strike-slip movement during the Late Jurassic – Early Cretaceous breakup of Gondwana. This resulted in a series of small fault-controlled sub-basins (Bredasdorp, Pletmos, Gamtoos and Algoa basins) with each comprising of rift half- graben overlain by variable thickness of syn-drift sediments (King, 1951; Haughton, 1969; Truswell, 1970; Du Toit, 1954). The deepwater extensions of these basins (excluding the Algoa basin) merge into the Southern Outeniqua Basin where the Mesozoic sediments attain a thickness of about 8000m (Broad *et al.,* 2012).

These basins have significant onshore and offshore components. compared to the other South African offshore basins.
The Algoa basin consists of the half- grabens: the predominantly onshore Sundays River Trough , the onshore and offshore Uitenhage Trough, and the offshore Port Elizabeth Trough (Fig. 2).

It also consists of the cretaceous Uitenhage Group that is of interest in the Southern Cape province, reaching its maximum development onshore in the Algoa Basin. It is subdivided into three major lithological units: Enon Formation, Kirkwood Formation and the Sundays River formation (McLachlan and McMillan, 1976). The Sundays River formation, which is under investigation in this study, is described as consisting of grey clays, silts and sands of shallow-water marine and estuarine origin. (Winter, 1973). Cyclic transgressive –regressive sequences are shown in the section in the CO 1/67 core. Invertebrate fossils have been recorded in this formation while vertebrate remains are extremely rare. This formation is proposed to be lowermost Valanginian – Hauterivian (Table1).

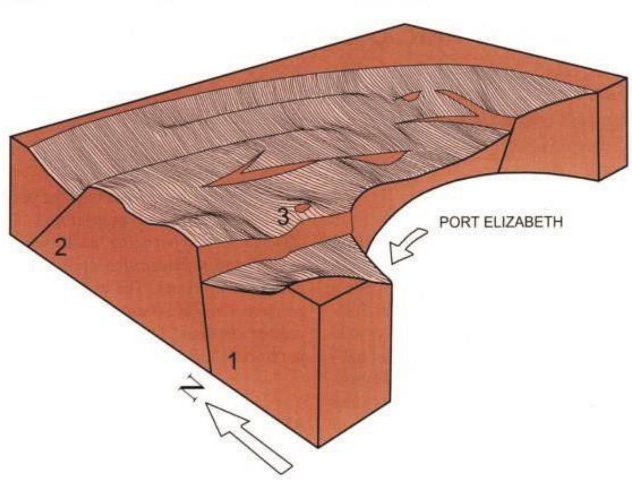

Figure 2: Major structural elements of the Algoa basin (braod *et al.,* 2012).

Table 1: Cretaceous type formations with their relative ages.

Formation (F) / Member (M)	Age	Macro/Micropala entology	Source of name	Type Section or Stratotype (S) / Locality of type area (A)	Basin Location	Proposer/reference
Agulhas Shale (F)	Upper Cretaceous – Lower Teriiary	-	Agulhas Bank	Borehole Ga-A2	Pletmos Basin (Offshore)	Du Toit (1976); Winter (1979)
Sundays River (F)	Lowermost Valnginian - Hauterivian	Foraminifera and ammonite assemblages	Sundays River, Zoetgeneugd Farm	Cliffs on the rightbank of the farm S of Addo (S). Borehole CO 1/67 (30-1028m) (S)	Algoa Basin (Onshore)	Wyley, (1859); Truswell, (1968); Winter, (1973); Shone, (1976); Du Toit, (1976 – offshore)
Infanta (F)	Upper Jurassic – Lower Cretaceous	Foraminifera	Cape Infanta	Borehole Gb-Gemsbok I and Gb-Springbok I (S-composite)	Pletmos Basin (Offshore)	Du Toit (1974) (to Working Group 1976)
Kirkwood (F)	Upper Jurassic – Lower Cretaceous: Tithonian - Valanginian	Fossil biota, freshwater crustaceans, bivalves, insects, fish scales, reptiles and mammalian bones.	Town of Kirkwood	Area S and E of the town (A) (Houghton 1928). Borehole CO 1/67 (1027-2280m) and CO 3/70 (2278-2370m)	Algoa Basin (onshore)	Winter 1973
Enon	Upper Jurassic – Lower Cretaceous	-	Mission Village (Enon Village) 64 km N of Port Elizabeth.	Environs of village (A)	Algoa Basin (onshore)	Atherstone (1857); Truswell (1967); Winter (1973, 1979)

MATERIALS AND METHODOLOGY

The outcrop samples were obtained from the Sunday's River type section on the right bank of the Sundays River at Eb en Vloed Farm (33'612, 25'648) opposite Zoetgeneugd Farm, south of Addo for the present investigation. The section was logged and 12 samples were selected from the lithological discrepancies for detailed study.

Laboratory technique for the extraction of palynological organic matter

Samples from different lithologies were subjected to the updated traditional palynomorph extraction technique by James B. Riding (2021), based on mineral acid digestion of the sample, matrix, and is subdivided into four phases. These are:

Phase 1: Sampling and pre-preparation Clay/silt-rich, fresh (unweathered), uncontaminated samples which were well geographically and stratigraphically constrained were collected and placed immediately in a brand new, clean, clearly- labelled, robust and securely sealable plastic bags to protect them from contamination during transportation and storage. They were thoroughly cleaned and carefully fragmented to a suitable weight of material.

Phase 2: Acid digestion

The material was carefully treated with ~40% hydrochloric acid to dissolve the carbonate minerals; when the reaction was complete, and the residue was decant washed to neutrality. The neutralised post- hydrochloric acid residue very carefully treated with ~40% hydrofluoric acid to digest as much of the silicate minerals present as possible and stirred at least daily; when the sediment matrix had broken down, the residue was decant washed to neutrality.

Phase 3: Palynomorph concentration

The residue was thoroughly washed with water, and the remaining organic matter was initially oxidized with nitric acid to remove extraneous organic material followed by 10% KOH treatment to remove the humic substances produced by oxidation. The material went through centrifugation to separate the residual mineral grains and heavy fragments of woody material using ultrasonic treatment briefly. Then the small fragments were sieved away. Finally both coarse and fine extraneous materials were separated from the palynomorphs by sieving, then the palynomorphs were concentrated into a small volume (10–15 ml) of aqueous residue.

Phase 4: Presentation of palynomorphs

Finally, the residue was mounted on glass slides with the help of glycerol jelly to prepare permanent slides. The hot plate was made ready at a low temperatures such that the hand, resting on the surface, was warm/hot. A vial of glycerol jelly was placed in a water bath (approximately 50°C) to melt the glycerol jelly. Slides were appropriately numbered with a diamond-tipped pencil; cleaned and place on a rack on the hot plate to warm. Coverslips were cleaned.

The residue was then stirred with a pipette to ensure even palynomorph dispersal before placing a drop or two on a prepared slide on hot plate depending on how dark the residue was. Slides were warmed (to evaporate off excessive moisture) but not dried. A drop or melted glycerol jelly was then added via a small glass rod. The residue and jelly were mixed thoroughly on central portion of slide using a clean dissecting needle while avoiding overheating. The cover slip was angled over the jelly/residue mixture on the slide and, with the aid of a needle, gently lowered onto the slide while allowing the mixture to flow to all edges of the cover slip.

The slides we then removed from heat and left cover slip down, for several hours at least to set for 2-3 days. Any excess residue/jelly around the edges of cover slips were removed using a razor blade and slides wiped clean with tissue dampened with alcohol and labeled with a permanent marker permanent.

Slide analysis procedure

The microscope used is Olumpus (CX31RBSFA) trinocular with 3mp USB 2.0 Color CMOS Amscope Digital eyepiece microscope camera.
At least 15 to 20 non-overlapping traverses were made to completely scan each slide while the Absolute Count (Quantitative Method) was maintained for all the slides during analysis. Every palynomorph identified while scanning was captured using the microscope camera.

RESULTS AND DISCUSSION

The type section consists of Alternating beds of grey shales, silts and sandstone (Fig 3 and 4).

Shale

The shale beds are predominantly soft, dark to light grey, ranging from highly fissile to non-fissile , very fine to fine grained, fossiliferous (organic dark patches at some regions), compact and coarsening upwards. Some shale beds were slightly arenaceous and friable. There was presence of carbonaceous particles in one of the lower shales of the section, slightly sandy with an oyster bed in the bottom unit.

Silt

The silt beds were fissile, dark grey to brow, had wood fragments and fine grained.

Sandstone

The sandstone beds were yellow, dark grey to brown in colour, fine grained and had organic matter imprints. A Bivalve band was present at the top of one of the sandstones ass the lithology transitioned into a shale bed.

Palynological Analysis

The studied interval is predominantly characterized by late Jurassic and early Cretaceous palynoflora which included *Oligosphaeridium pulcherrimum, Araucariacites australis, Classopollis classoides, Callialasporites dampieri, Cyathidites minor, Cicatricosisporites sp. Gleicheniidites senonicus, Foveosporites canalis, Klukisporites scaberis, Ruffordiaspora australiensis, Aequitriradites spinulosus, Coronifera oceanica* etc. (fig 5 and 6).

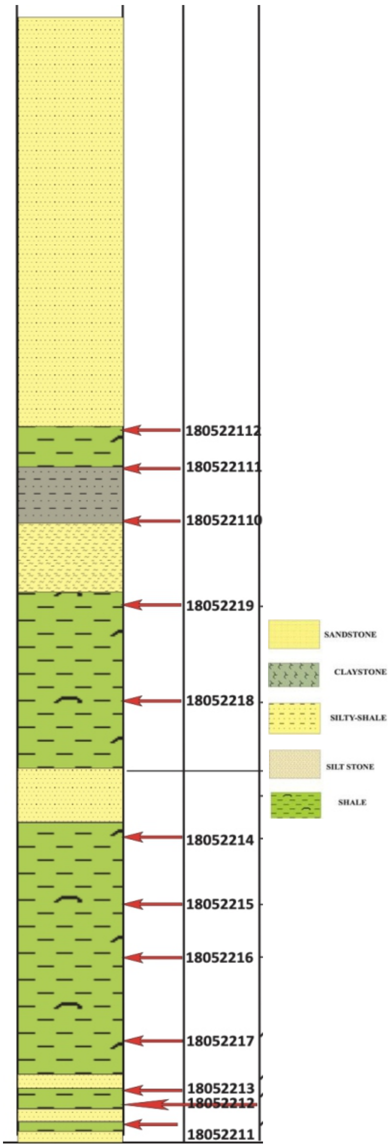

Figure 3: Litholog of the type section at Eb en Vloed farm, south of Addo.

Figure 4: Sundays River Type Section, Eb en Vloed Farm, Algoa Basin, South Africa. Person's height; 1.55m.

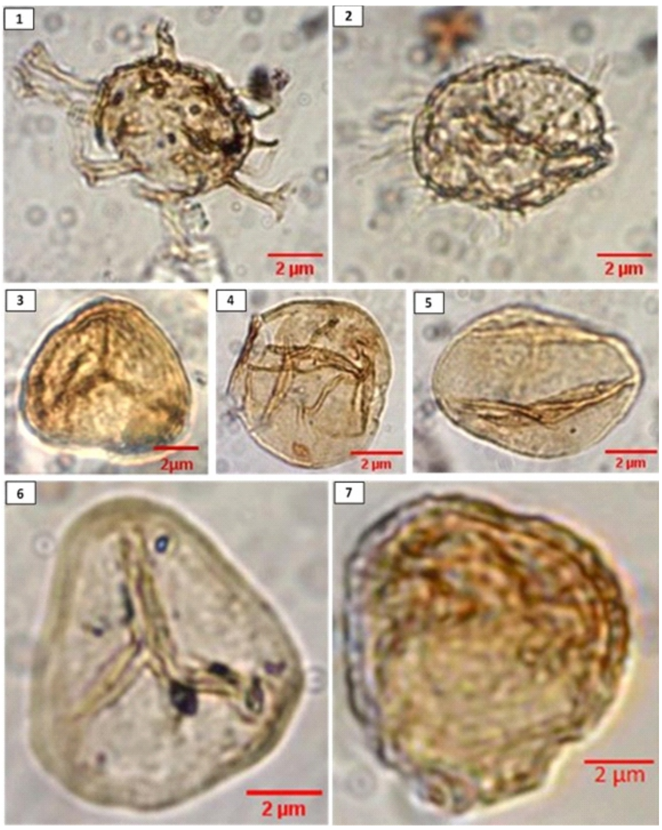

Figure 5: Oligosphaeridium pulcherrimum, Slide no: 1805221.9; 2. Coronifera oceanica, Slide no: 1805221.9; 3. Foveosporites canalis, Slide no: 1805221.10; 4. Araucariacites australis, Slide no: 1805221.11; 5. Classopollis classoides, Slide no: 1805221; 6. Cyathidites minor, Slide no: 1805221.1; **7.** Callialasporites trilobatus, Slide no: 1805221.6.

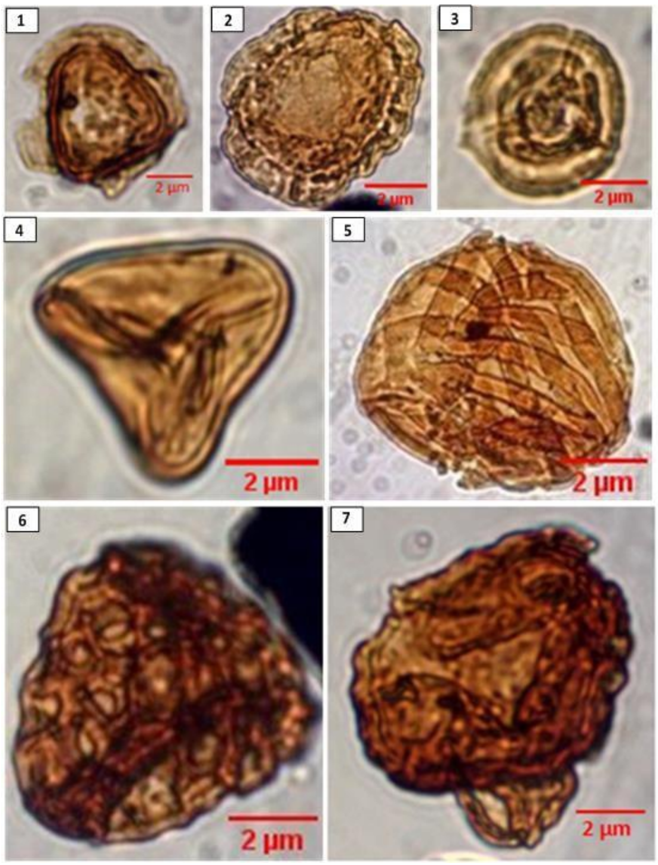

Figure 6: 1. Aequitriradites acusus Slide no: 1805221. 11;
2. Callialasporites dampieri Slide no: 1805221;
3. Aequitriradites spinulosus, Slide no: 1805221.4;
4. Gleicheniidites senonicus, Slide no: 1805221.3;
5. Cicatricosisporites sp. Slide no: 1805221.11; ;
6. Klukisporites scaberis, Slide no: 1805221.10A;
7. Ruffordiaspora australiensis, Slide no: 805221.10A.

The palynofloral assemblage is characterized into the *foraminisporis wonthagiensis* of Burger (1994) which corresponded to the early Cretaceous (Valanginian – Hauterivian) age.

Valanginian age: Valanginian is indicated with Top (Last Appearance Datum) of *Callialasporites dampieri* (Jurassic – Valanginian) and Continuous Occurrence (CO) of long stratigraphic ranged, late Jurassic/early Cretaceous palynoflora such as *Foveosporites canalis, Klukisporites scaberis, Ruffordiaspora australiensis* etc. *(fig 6)*

Top of Valanginian is indicated with Top (Last Appearance Datum) of *Callialasporites trilobatus* (Berriasian – Valanginian) at sample 1805221.2.

The Base of Valanginian in the studied section is undiagnostic, the base of the studied section is characterized with stratigraphic long ranging late Jurassic – early Cretaceous palynoflora.

Hauterivian age: Hauterivian in the studied section is indicated with the First Appearance Datum (FAD) of *Aequitriradites spinulosus / Aequitriradites acusus* (Hauterivian – Barremian) and First Appearance Datum (FAD) of *Coronifera oceanica,*

Top of Hauterivian in the studied section is undiagnostic. Top of the studied section consists of Hauterivian but with the presence of stratigraphic long ranging early Cretaceous palynoflora.

Base of Hauterivian corresponded to Top of Valanginian.

CONCLUSION

According to the results above the Sundays River formation is Valanginian to Hatuerivian in age. The carbonaceous material and dinoflagellates suggest a shallow marine environment however this would need more data to substantiate it.

More intensive work or investigations still needs to be done using samples from other sections as well as correlation with well samples both from onshore and offshore if possible, to further cement the conclusions of this investigation and help refine the stratigraphic framework of the Uitenhage Group.

REFERENCES CITED

Broad, D.S., Jungslager, E.H.A., McLachlan, I.R., Roux, J., 2012. South Africa's Offshore Mesozoic Basins. In: Phanerozoic Passive Margins, Cratonic Basins and Global Tectonic mas

Burger, D., 1994. Palynology of Mesozoic dredge samples from the North West Shelf. AGSO J. Aust. Geol. Geophys. 1, 89–100.

De Swardt, A.M.J., McLachlan, I.R., 1982. Petroleum exploration in the South African offshore: the geological framework and hydrocarbon potential. In: Glen, H.W. (Ed.), Proceedings of the 12th CMMI Congress, Johannesburg, S. Afr. Inst. Min. Metall., pp. 147–161.

Dingle, R.V., 1973. Post-Palaeozoic stratigraphy of the eastern Agulhas Bank, South African continental margin: Mar. Geol., 15, p. 1-23Dingle, R.V. and Scrutton, R.A. (1974) Continental break-up and the development pf post-Paleozoic sedimentary basins around Southern Africa. Geol. Soc. Am. Sull., 85, 1467-1474

Du Toit, S.R., 1976. Mesozoic geology of the Agulhas Bank, South Africa: Ph.D. thesis, Univ. Cape Town (unpubl.).

Emery, K.O., Uchupi, E., Bowin, C.O., Phillips, J. and Simpson, E.S.W. (1975) Continental margin off Western Africa: Cape St. Francis (South Africa) to Walvis Ridge (South West Africa). Am. Assoc. Petr. Geol. Sull., 59, 3-59

Jungslager, E. (1999). Petroleum habitats of the Atlantic margin of SouthAfrica. In: N.R. Cameron, R. H. Bate and V. S. V.S (Editors.), The oil andgas habitats of the South Atlantic, Geological Society, London, SpecialPublication, 153, 153-168 (PDF) Insights into the Petroleum System Evolution of the southern Orange Basin, South Africa.

McLachlan, I.R. and McMillan, I.K, 1976. Review and stratigraphic significance of southern Cape Mesozoic palaeontology: Trans. Geol. Soc. S. Afr., 79(2), p. 197- 212.

McMillan, I.K., Brink, G.I., Broad, D.S. and Maier, J.J., 1997. Late Mesozoic sedimentary basins off the south coast of South Africa. Sedimentary Basins of the World, 3, 319-376.

Riding JB, 2021. A guide to preparation protocols in palynology, Palynology. Shone, R.W., 1976. The sedimentology of the Mesozoic Algoa Basin. Unpublished M.Sc. thesis, University of Port Elizabeth, 48p.

Shone, R.W., 1976. The sedimentology of the Mesozoic Algoa Basin. Unpublished M.Sc. thesis, University of Port Elizabeth, 48p.

Simpson, E.S.W. and Dingle, R.V. (1973) Offshore sedimentary basins on the southeastern continental margin of South Africa. In Blant, G., ed., Sedimentary basins of the African coasts: Pt 2. South and east coasts. Paris, Assoc. African Geol. Survey. 63-68.

Truswell, J.F., 1968. A critical review of stratigraphic terminology as applied in South Africa. Transactions of the Geological Society of South Africa, 70, 81-116.

Winter, H. de la R., 1973. Geology of the Algoa Basin, South Africa: in Blant, G. ed.: Sedimentary basins of the African coasts, 2nd part South and East Coast: Assoc. Afr. Geol. Survs, Paris, p. 17-48.

Wyley. A., 1859. Notes on a journey in two directions across the Cape Colony, made in the character and order of the various geological formations: Appendix to Parliamentary Rep. G. 54-59, Cape Town, Cape of Good Hope, 61 p.

1805221.1
1805221.2
1805221.3
1805221.7
1805221.6
1805221.5
1805221.5
1805221.4
1805221.8
1805221.9
1805221.10
1805221.11
Sample Identity
Early Cretaceous
Valanginian
Hauterivian
Period/Epoch
Age
Chronostratigraphy
Foraminisporis wonthaglensis
Zone
Burger (1995)
Lithology and Grain Size
Lithology:
Silty shale
shale
sand (fine - medium)
silty sandstone
Acrostichumsporites sp. 2
Aratrisporites sp
Araucariacites australis
Callialasporites dampieri
Cicatricosisporites avnimelechi
Classopollis classoides (tetrads)
Cyathidites minor
Cyathidites spp.
Deltoidospora delicata
Duplexisporites generalis
Graminidites spp.
Leiotriletes maxoides maxoides
Polypodiasceoisporites congoensis
Triplanosporites microsinuosus
Undulatisporites sinuosis
Alisporites diaphanus
Limbosporites lundbladii
Baculatisporites sp.
Buttinia andreevi
Carnisporites anteriscus
Cicatricosisporites sp.
Classopollis meyerianus
Classopollis torosus tetrads
Corollina sp.
Deltoidospora spp.
Gleicheniidites senonicus
Magnastriatites grandiosus
Monocolpites marginatus
Stereisporites seebergensis
Syncolporites marginatus
Todisporites spp.
Zlivisporis blanensis
Biretisporites sp.
Callialasporites trilobatus
Camarozonosporites ambigens
Cyathidites congoensis
Distaverrusporites sp
Ginkcocycadophytus retroflexus
Matonisporites crassiangulatus
Reticulosporis wehningensis
Triplanosporites sp.
Aequitriradites spinulosus
Afropollis jardinus
Balmeiopsis limbatus
Dictyophyllidites sp.
Laevigatisporites robostus
Monoporopollenites annulatus
Osmundacidites wellmannii
Reticulosporis semireticulatus
Retitriletes spp.
Rogalskaisporites cicatricosus
Acrostichum aureum
Anemia sp.
Cicatricosisporites australiensis
Cicatricosisporites brevilaesuratus
Cicatricosisporites minutaestriatus
Classopollis spp.
Clavatipollenites hughesii
Conbaculatisporites mesozoicus
Cyathidites australis
Cycadopites sp
Deltoidospora psilostomata
Exesipollenites sp.
Extrapunctatosporis miocaenicus
Foraminisporis asymetricus
Graminidites annulatus
Granuloperculatipollis rudis
Inaperturopollenites limbatus
Ischyoporites sp. 2
Kuylisporites lunaris
Laevigatosporites belfordii
Leptolepidites major
Lygodiumsporites adriennis
Marattisporites arcus
Polypodiaceoisporites retirugatus
Retimonocolpites variplicatus
Sculptisporis moretonensis
Sestrosporites pseudoalveolatus
Stereisporites antiquasporites
Stereisporites australis
Trilobosporites bernisartensis
Verrucatosporites pseudoregulatius
Zebrasporites interscriptus
Cicatricosisporites pramparoana
Clavatipollenites rotundus
Dictyophyllidites harrisii
Dictyophyllidites mortoni
cf. Leiotriletes lineatus
Osmundacidites alpinus
Tigrisporites halleinis
Aequitriradites dandaraganensis sp.
Cicatricosisporites potomacensis
Concavissimisporites verrucosus
Deltoidospora hallei
Foveosporites canalis
Januasporites multispinus sp.
Klukisporites lacunus
Klukisporites scaberis
cf. Matonisporites sp.
Neoraistrickia equalis
Osmundasporites sp.
Ruffordiaspora australiensis
Sphagnumsporites psilatus
Aequitriradites arcusus/spinulosus
Concavissimisporites punctatus
Cyclogranisporites sp.
Gleicheniidites peregrinus
Gleicheniidites spp.
Nevesisporites dailyi
Nevesisporites harleyi sp.
Nevesisporites undatus sp.
Trilobosporites hannonicus
Elytrocysta druggii
Operculodinium centrocarpum
Operculodinium eirikanium
Lanternosphaeridium reinhardtii
Diphyes digitum
Dipyhes colligerum
Exochosphaeridium truncatum
Spiniferites fluens
Surculosphaeridium longifurcatum
Coronifera oceanica
Florentinia berran
Oligosphaeridium pulcherrimum
Xiphophoridium alatum
Avellodinium lepidum sp.
Pseudoceratium anaphrissum
Absolute abundance (30mm=90 counts)
Spores And Pollen
Dinoflagellate Cysts
Top of Callialasporites dampieri (L
Top of Callialasporites trilobatus (L
Base of Aequitriradites spinulosus
Foveosporites canalis (CO),
Ruffordiaspora australiensis (CO),
Klukisporites scaberis (CO)
Base of Coronifera oceanica (FA
Oligosphaeridium pulcherrimum (C
Base of Aequitriradites acusus (FA
Events

NIGERIAN ASSOCIATION OF PETROLEUM EXPLORATIONISTS

SINCE 1975