CHAPTER 6

BIOSTRATIGRAPHY

6.1 SUMMARY POLLEN DIAGRAMS

A summary of the most important palynomorph groups for each borehole are presented in Figures 6.1 and 6.2 and are discussed in more detail in Chapter 8.

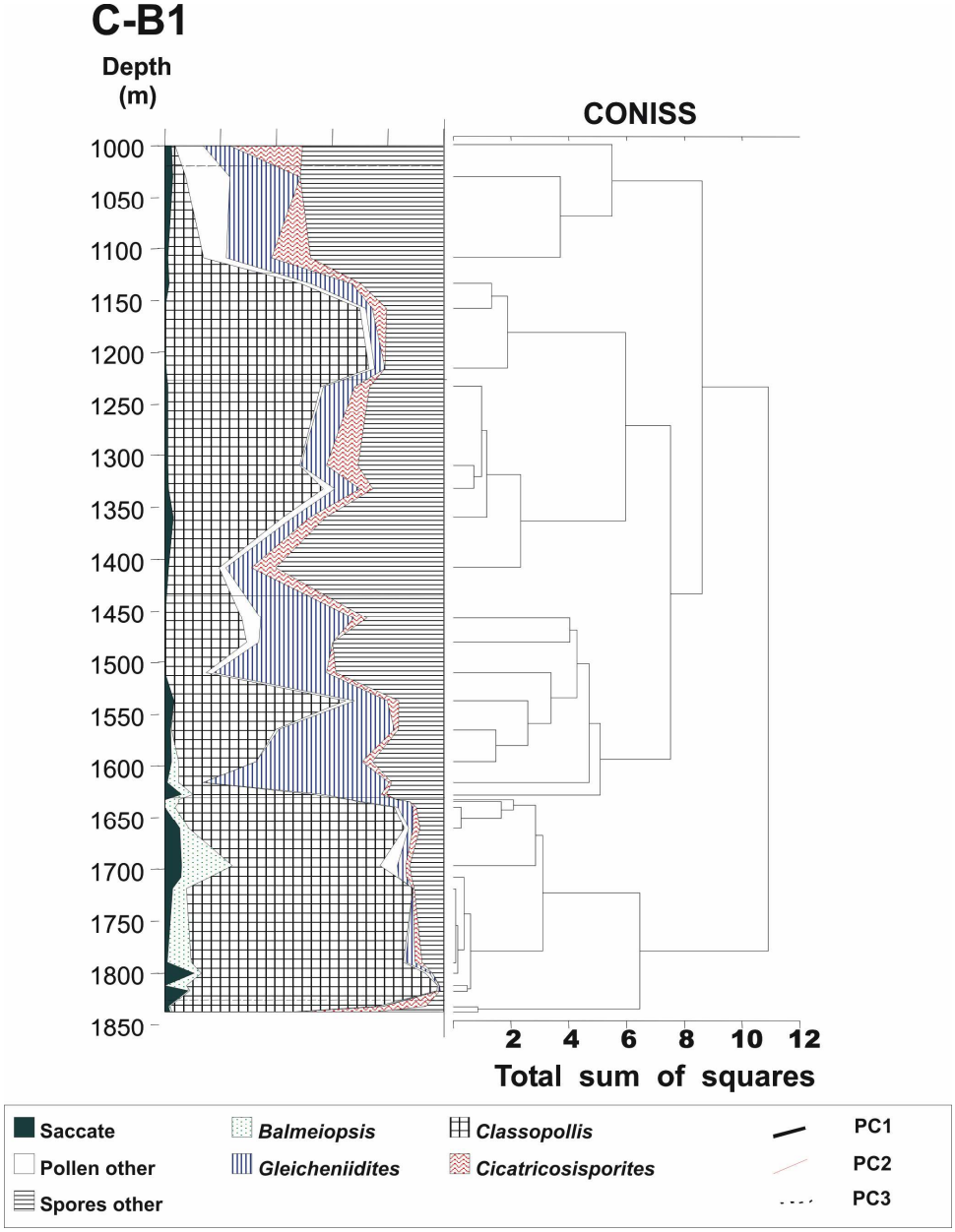


Figure 6.1. Summary pollen diagram for Offshore Site C-B1.

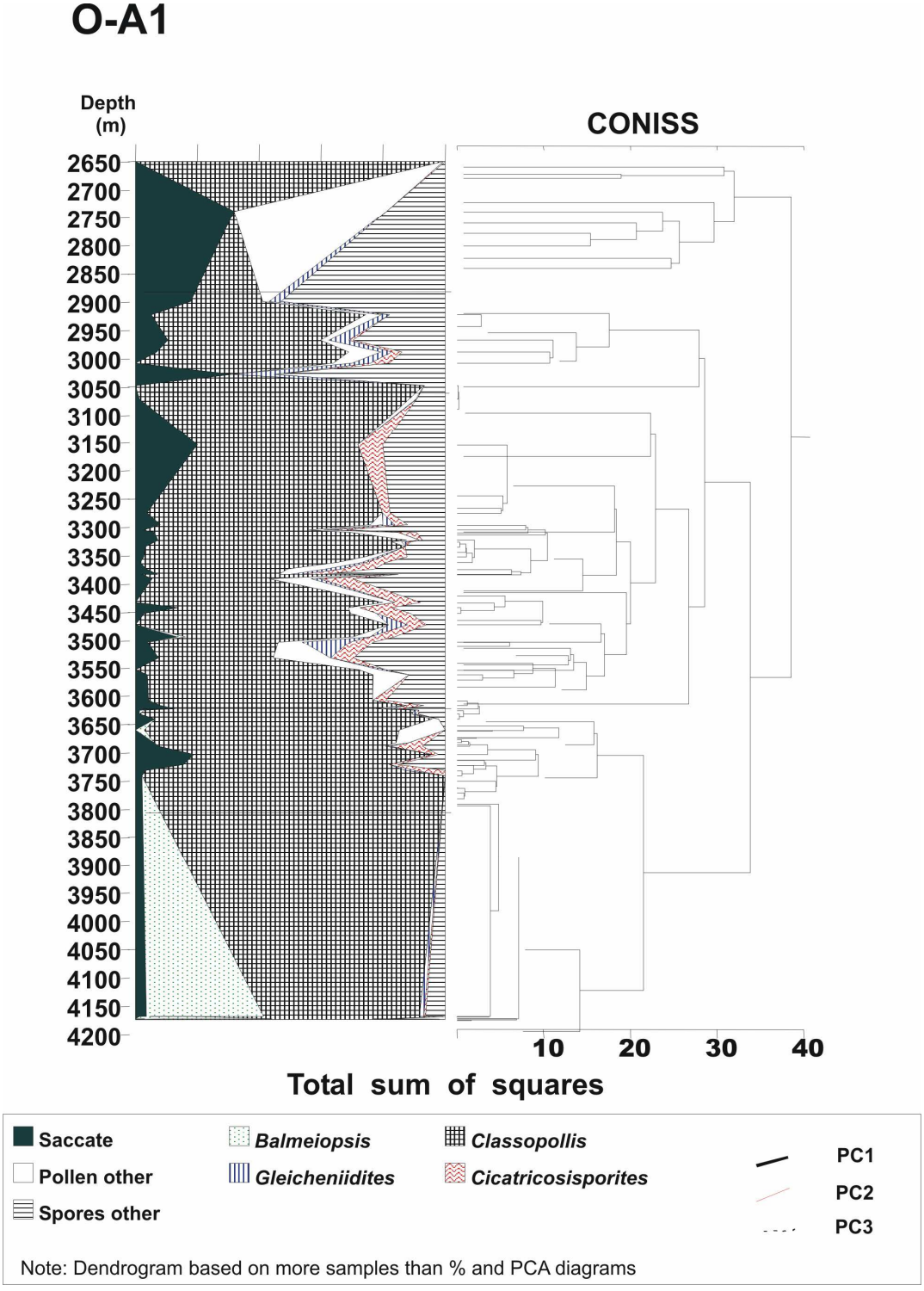


Figure 6.2. Summary pollen diagram for Offshore Site O-A1.

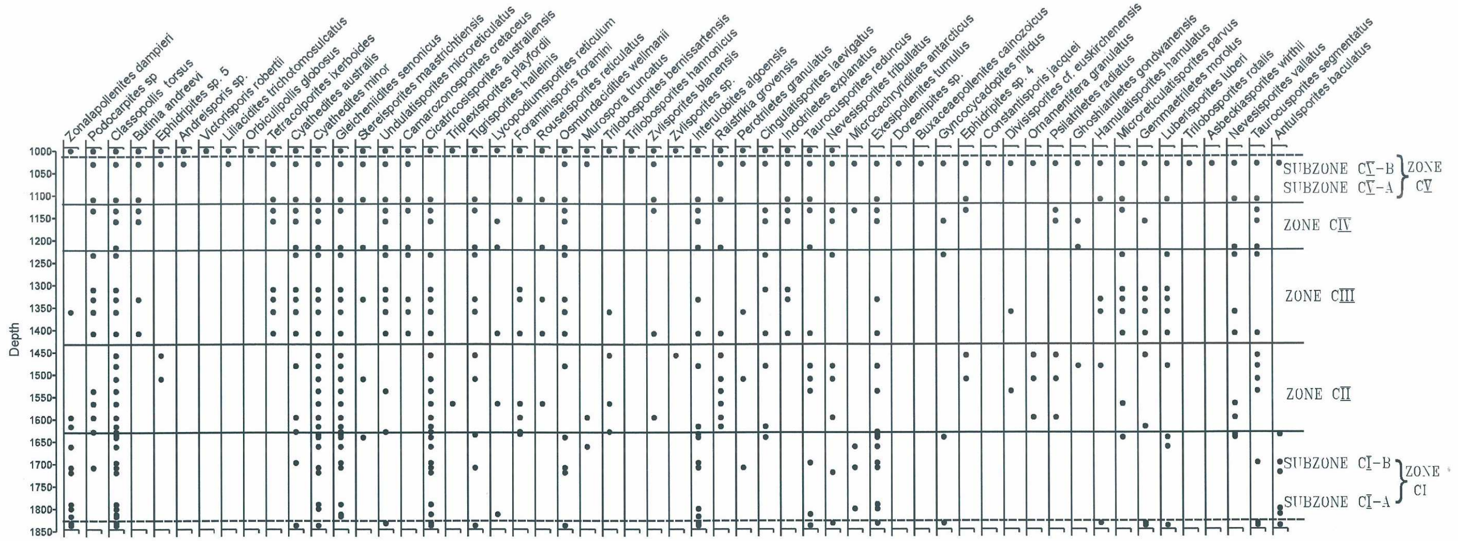
6.2 BIOSTRATIGRAPHIC DISTRIBUTION FOR OFFSHORE SITE C-B1

The down-hole biostratigraphic distribution of the pollen grains and trilete spores from both Offshore Sites is shown in Figures 6.3 and 6.4 (See Appendix 5 for the enlarged diagrams). The species are arranged in order of their first appearance (first appearance datum in core) and their exact stratigraphic position within each Offshore Site is shown. The interpretations concerning the age and correlation of each zone are based mainly on the appearance and not necessarily the first appearance in a particular zone of any pollen grain or trilete spore that either has the required age range for that zone and/or is younger than the age of the zone it is found in. Any pollen grain or trilete spore that is older than the required age for a particular zone (i.e. Permian trilete spore in a Late Cretaceous zone) is excluded. Figures 6.3 and 6.4 can also potentially point out major catastrophic events.

As with the pollen diagrams in Chapter 4, each zone and subzone is labeled on the biostratigraphic distribution diagrams (Figures 6.3 and 6.4), however due to the limited space available between zones, a table (Table 6.1) has been constructed listing the zone or subzone and it's relevant age range. Tables 6.2. – 6. 8 have been included to help simplify the description and discussion of the relevant zone in Figure 6.3.

ZONE / SUBZONE	AGE RANGE
ZONE CI - Subzone CI - A - Subzone CI - B	Barremian Stage in age. Barremian to the Early Aptian stages in age.
ZONE CII	Aptian to the beginning of the Turonian Stage.
ZONE CIII	Beginning of the Turonian to the start of the middle Coniacian stages
ZONE CIV	Beginning of the middle Coniacian to the Late Coniacian stages.
ZONE CV - Subzone CV - A - Subzone CV - B	Late Coniacian to Early Santonian stages. Santonian to Campanian stages.

Table 6.1. A quick reference guide for zones / subzones and their relevant ages.


Zonalapollenites dampieri
Podocarpites sp
Classopollis torsus
Butinia andreevi
Ephidripites sp. 5
Andreisporis sp.
Victorisporis robertii
Liliacidites trichotomosulcatus
Orbiculipollis globosus
Tetracolporites ixerboides
Cyathedites australis
Cyathedites minor
Gleicheniidites senonicus
Stereisporites maastrichtiensis
Undulatisporites microreticulatus
Camarozonosporites cretaceus
Cicatricosisporites australiensis
Triplexisporites playfordii
Tigrisporites halleinis
Lycopodiumsporites reticulum
Foraminisporis foramini
Rouseisporites reticulatus
Osmundacidites wellmanii
Murospora truncatus
Trilobosporites bernissartensis
Trilobosporites hannonicus
Zlivisporites blanensis
Zlivisporites sp.
Interulobites algoensis
Raistrikia grovensis
Perotrilites granulatus
Cingulatisporites laevigatus
Indotriletes explanatus
Taurocusporites reduncus
Nevesisporites tribullatus
Microcachryidites antarcticus
Exesipollenites tumulus
Dorenipites sp.
Buxaceaepollenites cainozoicus
Gyncocycadopites nitidus
Ephidripites sp. 4
Constantisporis jacquei
Divisisporites cf. euskirchenensis
Ornamentifera granulatus
Psilatriletes radiatus
Ghoshiatriletes gondwanensis
Hamulatisporites hamulatus
Microreticulatisporites parvus
Gemmaetriletes morolus
Luberisporites luberi
Trilobosporites rotalis
Asbeckiasporites wirthii
Nevesisporites vallatus
Taurocusporites segmentatus
Antulsporites baculatus
Depth
1000
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500
1550
1600
1650
1700
1750
1800
1850
SUBZONE CⅤ-B
SUBZONE CⅤ-A
ZONE CⅤ
ZONE CⅣ
ZONE CⅢ
ZONE CⅡ
SUBZONE CⅠ-B
SUBZONE CⅠ-A
ZONE CI

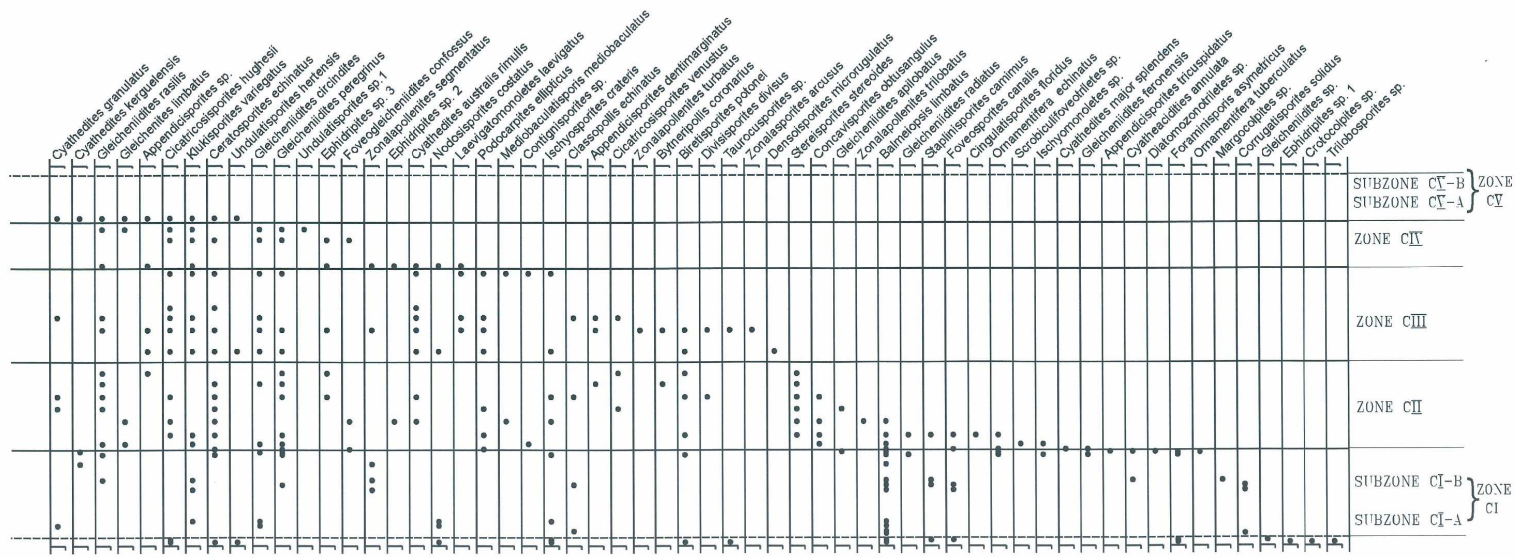

Cyathedites granulatus
Cyathedites kerguelensis
Gleicheniidites rasilis
Gleicheniidites limbatus
Appendicisporites sp.
Cicatricosisporites hughesii
Klukisporites variegatus
Ceratosporites echinatus
Undulatisporites hertensis
Gleicheniidites circinidites
Gleicheniidites peregrinus
Undulatisporites sp. 3
Ephidripites sp. 1
Foveogleicheniidites confossus
Zonalapollenites segmentatus
Ephidripites sp. 2
Cyathedites australis rimulis
Nodosisporites costatus
Laevigatomonoletes laevigatus
Podocarpites ellipticus
Mediobaculatisporis mediobaculatus
Contignisporites sp.
Ischyosporites crateris
Classopollis echinatus
Appendicisporites dentimarginatus
Cicatricosisporites venustus
Zonalapollenites turbatus
Bytneripollis coronarius
Biretisporites potonei
Divisisporites divisus
Taurocusporites sp.
Zonalasporites arcusus
Densoisporites microrugulatus
Stereisporites stereoides
Concavisporites obtusangulus
Gleicheniidites apilobatus
Zonalapollenites trilobatus
Balmeiopsis limbatus
Gleicheniidites radiatus
Staplinisporites caminus
Foveosporites canalis
Cingulatisporites floridus
Ornamentifera echinatus
Scrobiculifoveotriletes sp.
Ischyomonoletes sp.
Cyathedites major splendens
Gleicheniidites feronensis
Appendicisporites tricuspidatus
Cyatheacidites annulata
Diatomozonotriletes sp.
Foraminisporis asymetricus
Ornamentifera tuberculatus
Margocolpites sp.
Corrugatisporites solidus
Gleicheniidites sp. 1
Ephidripites sp.
Crotocolpites sp.
Trilobosporites sp.
SUBZONE CⅤ-B
SUBZONE CⅤ-A
ZONE CⅤ
ZONE CⅣ
ZONE CⅢ
ZONE CⅡ
SUBZONE CⅠ-B
SUBZONE CⅠ-A
ZONE CI

Figure 6.3. Age and correlation of microflora in Offshore Site C-B1.

6.2.1 STRATIGRAPHIC DISTRIBUTION WITHIN SUBZONE CI -A OF OFFSHORE SITE C-B1

During the Barremian, columellate semi-tectate tricolpate pollen appears for the first time in

SUBZONE CI - A, THE BARREMIAN STAGE		
GEOLOGY:	**PALYNOMORPHS PRESENT:**	**ABUNDANCE:**
This zone represents an early rift environment with sediments deposited into a shallow sheltered sea with limited bottom circulation.	Pollen and spores are abundant. No microplankton occurs in this zone.	33 species are present: 7 species of pollen grains 26 species of trilete spores

ENTRANCE LEVEL SPECIES:

Species with Early Cretaceous or younger entrance levels are listed below:

Crototricolpites sp. – Early Cretaceous

Antulsporites baculatus – Early Cretaceous

Biretisporites potoniaei – Early Cretaceous

Ceratosporites equalis – Early Cretaceous

Cicatricosisporites australiensis - Early Cretaceous

Cicatricosisporites hughesii – Early Cretaceous

Foraminisporis asymetricus – Early Cretaceous

Foveosporites canalis – Early Cretaceous

Gemmatriletes morolus – Late Cretaceous

Hamulatisporites hamulatus – Early Cretaceous

Interulobites algoensis – Early Cretaceous

Ischyosporites crateris – Early Cretaceous

Luberisporites luberi – Early Cretaceous

Nodosisporites costatus – Early Cretaceous

Taurocusporites reduncus – Early Cretaceous

Taurocusporites segmentatus - Early Cretaceous

Undulatisporites microcutis – Early Tertiary

Undulatitriletes hertensis – Early Tertiary

BIOSTRATIGRAPHIC CONCLUSION:

Five of the seven pollen grains are long-ranging and have been reported in strata older than the Barremian by many researchers. One pollen grain has a species designation and therefore does not have a defining age. Seventeen of the twenty six species of spores had entrance level requirements to classify this zone as Early Cretaceous in age. The other nine spores discarded were either Jurassic in age or older or had species designations. The geology of the area was also taken into consideration, as this part of the Offshore Site is known to be Early Cretaceous in age so the entrance level palynomorphs age corresponds to the known age of the region. *Crototricolpites* sp. is not an indicator

species, but its presence isolates this zone specifically to the Barremian Stage.

Table 6.2 The biostratigraphy of Subzone CI - A, Offshore Site C-B1.

palynofloras that range from southern England (Hughes *et al.,* 1979), Israel (Brenner, 1984), West Africa, Argentina as well as the eastern part of North America (Hickey & Doyle, 1977) to Equatorial Africa (Doyle *et al.,* 1977). Hughes *et al.,* (1979), found that the abundance of Barremian tricolpate floras in his region of study (southern England) was typically less than 1 %.

The geology of this part of Offshore Site C-B1 is known to be Early Cretaceous in age (research done by the Petroleum Agency, SA) and specified by the Petroleum Agency, SA as the Barremian Stage. The palynomorphs in Table 6.2 are included there because they have the entrance level age requirements for the Early Cretaceous i.e. they are not found in strata older than the Early Cretaceous. Four species did not crossover into Subzone CI – B from Subzone CI - A and one of these was a single tricolpate pollen grain, *Crototricolpites* sp., with columellate semi-tectate sculpture that could possibly isolate Subzone CI - A specifically to the Barremian Stage.

The overall age of the palynomorphs present corresponds to the known generalized age of Sub-zone CI - A, that is the Early Cretaceous and the presence of a single tricolpate pollen grain with columellate semi-tectate sculpture suggests the Barremian Stage.

6.2.2 STRATIGRAPHIC DISTRIBUTION WITHIN SUBZONE CI - B OF OFFSHORE SITE C-B1

The geology of this part of Offshore Site C-B1 as with Subzone CI - A is known to be Early Cretaceous in age and specified by the Petroleum Agency, SA as the Barremian to Aptian stages. The palynomorphs in Table 6.3 are included there because they have the entrance level age requirements (the required age for Subzone CI – B and younger) for the Early Cretaceous.

There are no indicator species present in this zone to isolate this region specifically to the Barremian and Aptian stages however there is a single mostly psilate tricolporate pollen grain (*Margotricolporites* sp.) found in the last few meters of the Barremian Stage of this zone to suggest that Subzone CI – B may be Barremian in age.

SUBZONE CI - B, THE BARREMIAN TO EARLY APTIAN STAGES

GEOLOGY:	**PALYNOMORPHS PRESENT**:	**ABUNDANCE:**
Subzone CI - B represents the Early Cretaceous of the South Atlantic early to late rift period.	Land derived pollen and spores occur in association with scattered occurrences of marine dinoflagellates. These appeared at the start of Subzone CI - B together with fungal spores.	52 species are present: 10 species of pollen grains 41 species of trilete spores

ENTRANCE LEVEL SPECIES:

Species with Early Cretaceous or younger entrance levels are listed below:

Margoticolporites sp. - Early Cretaceous
Antulsporites baculatus – Early Cretaceous
Appendicisporites tricuspidatus – Early Cretaceous
Biretisporites potoniaei – Early Cretaceous
Ceratosporites equalis – Early Cretaceous
Cicatricosisporites australiensis – Early Cretaceous
Cingulatisporites levispecoisus – Early Cretaceous
Corrugatisporites solidus – Early Cretaceous
Cyatheacidites annulatus – Early Cretaceous
Foraminisporis asymetricus – Early Cretaceous
Foraminisporis foraminis – Early Cretaceous
Foveosporites canalis – Early Cretaceous
Gemmatriletes morolus – Late Cretaceous
Gleicheniidites feronensis – Early Cretaceous
Gleicheniidites peregrinus – Early Cretaceous
Gleicheniidites radiatus – Early Cretaceous – Aptian
Gleicheniidites rasilis – Early Cretaceous – Aptian
Hamulatisporites hamulatus – Early Cretaceous
Interulobites algoensis – Early Cretaceous
Ischyosporites crateris – Early Cretaceous
Luberisporites luberi – Early Cretaceous
Microreticulatisporites parviretis – Early Cretaceous
Nodosisporites costatus – Early Cretaceous
Ornamentifera echinatus – Early Cretaceous
Ornamentifera tuberculatus – Early Cretaceous
Stereisporites electoides – Tertiary
Taurocusporites reduncus – Early Cretaceous
Taurocusporites segmentatus – Early Cretaceous

BIOSTRATIGRAPHIC CONCLUSION:

Eight of the ten pollen grains are long-ranging and have been reported in strata older than the Barremian by many researchers. One pollen grain has a species designation and therefore does not have a defining age. Twenty seven of the fourty one species of spores had the entrance level requirements to classify this zone as Early Cretaceous only. The other fourteen spores discarded were Jurassic in age and older or had species designations. The generalized age of the palynomorphs present reflects the same age as the geology of this area. There are no indicator species present in this zone either so isolating this zone specifically to the Barremian and Aptian stages is possible based only on the appearance of a single angiosperm pollen found in the Barremian and two species of *Gleicheniidites* namely *Gleicheniidites radiatus* and *Gleicheniidites rasilis* that are known to be make their first appearances during the Aptian stage so taking the geology and the microflora into consideration, a Barremian to Aptian age can been concluded.

Table 6.3. The biostratigraphy of Subzone CI - B, Offshore Site C-B1.
Five species disappeared at the end of this zone representing the start of the Aptian Stage. Of these, *Foraminisporis asymetricus* is an Early Cretaceous species that according to other researchers (Krutzsch, 1959 & Dettman, 1963) makes its last appearance during the Aptian Stage. *Gleicheniidites radiatus* and *Gleicheniidites rasilis* that are both present in this zone and are known to make their first appearances during the Aptian Stage (Krutzsch, 1959), so taking the geology and the microflora into consideration, this zone can specifically be isolated to the Barremian and start of the Aptian stages.

Sea levels were high during the Barremian Stage (Haq *et al.,* 1987) however the end of Subzone CI - B heralded in the start of the Aptian Stage and with it a change in sea level.

6.2.3 STRATIGRAPHIC DISTRIBUTION WITHIN ZONE CII OF OFFSHORE SITE C-B1

Zone CII is an Early Cretaceous / Late Cretaceous transition zone (Gradstein *et al.,* 2004) where the crossover occurs at approximately the 1540 m level.

The Aptian regressive phase can be seen at the start of Zone CII in Figure 6.4. This regression has noticeably affected the flora and in turn the microflora of this zone. Six of the twelve species that disappeared and did not reappear again anywhere in this Offshore Site disappeared during the Aptian regression. *Gleicheniidites radiatus* appears to have disappeared at the end of the Aptian Stage having made its first appearance at the beginning of that same stage. This suggests that *Gleicheniidites radiatus* could be an indicator species for the Aptian Stage.

Three species disappeared during the Albian Stage namely *Balmeiopsis limbatus, Gleicheniidites apilobatus* and *Zonalapollenites turbatus.* They all disappeared from the strata record at some stage during the Albian and also represents the close of the Early Cretaceous. These three species cannot affirm this age but they can support this interval of Zone CII as the Early Cretaceous.

A second regressive event occurs during the middle part of the Cenomanian Stage. This with-drawl appears to have been less aggressive as it was not preserved in the drilled sequences (See

Chapter 5). Figure 6.3, Zone CII, supports this as no line of microfossil extinction occurs between the1480 m and 1460 m level.

<table>
<tr><th colspan="3">ZONE CII, THE APTIAN, ALBIAN, CENOMANIAN & EARLY PART OF THE TURONIAN STAGE</th></tr>
<tr><td>GEOLOGY:
This zone represents the crossover between the Early to the Late Cretaceous periods i.e. late rift to early drift phases.</td><td>PALYNOMORPHS PRESENT:
Land derived pollen and spores occur in association with scattered occurrences of marine dinoflagellates.</td><td>ABUNDANCE:
74 species are present:
13 species of pollen grains
61 species of trilete spores</td></tr>
<tr><td colspan="3">ENTRANCE LEVEL SPECIES:
Species with Early Cretaceous or younger entrance levels are listed below:
Bytneripollis coronarius – Early Tertiary
Appendicisporites dentinarginatus – Early Cretaceous
Appendicisporites tricorinatatus – Early Cretaceous
Biretisporites potoniaei – Early Cretaceous
Ceratosporites equalis – Early Cretaceous
Cicatricosisporites australiensis – Early Cretaceous
Cicatricosisporites hughesii – Early Cretaceous
Cicatricosisporites venustus – Late Cretaceous
Cingulatisporites levispecoisus – Early Cretaceous
Divisisporites divisus – Early Tertiary
Divisisporites euskirchenensis – Early Tertiary
Foraminisporis foraminis – Tertiary
Foveogleicheniidites confossus – Late Cretaceous
Foveosporites canalis – Early Cretaceous
Gemmatriletes morolus – Late Cretaceous
Gleicheniidites apilobatus – Early Cretaceous
Gleicheniidites feronensis – Early Cretaceous
Gleicheniidites peregrinus – Early Cretaceous
Gleicheniidites radiatus – Early Cretaceous
Gleicheniidites rasilis – Early Cretaceous
Gleicheniidites toriconcavus – Early Cretaceous
Gleichenites limbatus – Early Cretaceous
Hamulatisporites hamulatus – Early Cretaceous
Interulobites algoensis – Early Cretaceous
Ischyosporites crateris – Early Cretaceous
Luberisporites luberi – Early Cretaceous
Mediobaculatisporites mediobaculatus – Tertiary
Microreticulatisporites parviretis – Early Cretaceous
Nodosisporites costatus – Early Cretaceous
Ornamentifera echinatus – Early Cretaceous
Ornamentifera tuberculatus – Early Cretaceous
Psilatriletes radiatus – Early Cretaceous
Stereisporites electoides – Tertiary
Stereisporites stereoides – Tertiary
Taurocusporites reduncus – Early Cretaceous
Taurocusporites segmentatus – Early Cretaceous
Undulatisporites microcutis – Early Tertiary
Zvlisporis blanensis – Early to Late Cretaceous</td></tr>
<tr><td colspan="3">BIOSTRATIGRAPHIC CONCLUSION:
Eight of the thirteen pollen grains are long-ranging and have been reported in strata older than the Early Cretaceous. Five pollen grains have species designations and therefore do not have a defining age but Bytneripollis coronarius has an acceptable entrance level age (middle part of the Tertiary). Thirty seven of the sixty one species of spores had the entrance level requirements to classify this zone as Early to Late Cretaceous only. The other twenty four spores discarded were Jurassic in age and older or had species designations. The geology of the area as well as the Aptian regressive event that was registered in the palynoflora was taken into account so this part of the Offshore Site is known to be Early / start Late Cretaceous, late rift, early drift periods in age. There are no indicator species present to isolate this zone specifically to the Early Cretaceous / Late Cretaceous periods however, there are seventeen species present that are known to be make their first appearances during the Early Cretaceous and seven species are Late Cretaceous and younger in age. The geology, Aptian regression and the microflora suggests an Early Cretaceous / Late Cretaceous crossover age for this Zone CII.</td></tr>
</table>

Table 6.4. The biostratigraphy of Zone CII, Offshore Site C-B1.

Bytneripollis coronarius makes its first appearance during the Cenomanian Stage and *Concavisporites obtusangulus* makes its last appearance during the same period. *Concavisporites obtusangulus* like *Bytneripollis coronarius* has a known Tertiary age (See Appendix 2) and cannot be used to support a Cenomanian age or identify any part of the Cretaceous Period with certainty. The presence of the Tertiary palynomorphs are due either to contamination or their ages could extend back into the Cretaceous Period

Stereisporites stereoides makes its last appearance during the start of the Turonian Stage. This species also has a known Tertiary literature age and therefore as with *Bytneripollis coronarius* and *Concavisporites obtusangulus* cannot be used to identify any part of the Cretaceous with certainty.

There are a few species present to isolate this zone specifically to the Early Cretaceous, however a Late Cretaceous age is supported by the seven species that have entrance level ages (the required age for Zone CII and younger) of Late Cretaceous and younger (Table 6.4). By combining the Aptian and Cenomanian regressive events with the entrance level age requirements of the palynomorphs, an Early Cretaceous / Late Cretaceous transition age for this Zone CII.

6.2.4 STRATIGRAPHIC DISTRIBUTION WITHIN ZONE CIII OF OFFSHORE SITE C-B1

The geology of this part of Offshore Site C-B1 shows it to be Late Cretaceous in age and specified by the Petroleum Agency, SA as the Turonian and early to middle parts of Coniacian Stage. The palynomorphs in Table 6.5 are included there because they have the entrance level age requirements for the Late Cretaceous Period.

No indicator species occur that could isolate this zone specifically to the Turonian and /or Coniacian stages however, as with the Aptian regressive event, the Turonian regression impacted heavily on the flora with ten species disappearing at intervals over the Turonian Stage. Two of these species are known to be Tertiary representatives.

ZONE CIII, THE TURONIAN TO THE START OF THE MIDDLE PART OF THE CONIACIAN STAGE		
GEOLOGY: This zone represents the Late Cretaceous, early drift phases with Africa and South America effectively separated from each.	**PALYNOMORPHS PRESENT:** Land derived pollen and spores occur in association with scattered occurrences of marine dinoflagellates.	**ABUNDANCE:** 62 species are present: 12 species of pollen grains 50 species of trilete spores
ENTRANCE LEVEL SPECIES: Species with Late Cretaceous or younger entrance levels are listed below: *Buttinia andreevii* – K-T boundary *Bytneripollis coronarius* – Early Tertiary *Tetracolporites ixerboides* – Tertiary *Cicatricosisporites venustus* – Late Cretaceous *Divisisporites divisus* – Early Tertiary *Divisisporites euskirchenensis* – Early Tertiary *Foraminisporis foraminis* – Tertiary *Gemmatriletes morolus* – Late Cretaceous *Mediobaculatisporites mediobaculatus* – Tertiary *Undulatisporites microcutis* – Early Tertiary		
BIOSTRATIGRAPHIC CONCLUSION: Seven of the twelve pollen grains are long-ranging and have been reported in strata older than the Late Cretaceous by many researchers. There are two pollen grains which have species designations and therefore do not have a defining age but *Buttinia andreevii, Bytberipollis coronarius* and *Tetracolporites ixerboides* has an entrance level age of Late Cretaceous to Tertiary. Seven of the fifty species of spores had the entrance level requirements to classify this zone as Late Cretaceous. The other fourty three spores discarded were Late Cretaceous in age and older or had species designations. There are no indicator species present to isolate this zone specifically to the Turonian and middle part of the Coniacian Stage however as with the Aptian regression, the Turonian regression also impacted negatively on the flora. Taking the geology and the Turonian regression into consideration as well as the entrance level requirements of the palynomorphs, a Late Cretaceous age for Zone CIII can be concluded.		

Table 6.5. The biostratigraphy of Zone CIII, Offshore Site C-B1.

Four species disappear at the close of the early part of the Coniacian however none of these species could be isolated (first or last appearance) to this period. Combined with the Turonian regression and the entrance level age requirements of the palynomorphs, a Late Cretaceous age for Zone CIII is concluded.

6.2.5 STRATIGRAPHIC DISTRIBUTION WITHIN ZONE CIV OF OFFSHORE SITE C-B1

<table>
<tr><td colspan="3">ZONE CIV, THE MIDDLE PART OF THE CONIACIAN TO THE MIDDLE PART OF THE LATE CONIACIAN STAGE</td></tr>
<tr><td>GEOLOGY:
This zone represents early drift phases with Africa and South America effectively separated from each other and drifting further apart.</td><td>PALYNOMORPHS PRESENT:
Land derived pollen and spores occur in association with scattered occurrences of marine dinoflagellates.</td><td>ABUNDANCE:
48 species are present:
11 species of pollen grains
37 species of trilete spores</td></tr>
<tr><td colspan="3">ENTRANCE LEVEL SPECIES:
Species with Late Cretaceous or younger entrance levels are listed below:
Buttinia andreevii – K-T boundary
Tetracolporites ixerboides – Tertiary
Gemmatriletes morolus – Late Cretaceous
Undulatisporites microcutis – Early Tertiary</td></tr>
<tr><td colspan="3">BIOSTRATIGRAPHIC CONCLUSION:

Five of the eleven pollen grains are long-ranging and have been reported in strata older than the Late Cretaceous by some researchers. There four pollen grains have species designations and therefore do not have a defining age but Buttinia andreevii and Tetracolporites ixerboides has an entrance level age of Late Cretaceous to Tertiary. Only two of the forty eight species of spores had the entrance level requirements to classify this zone as Late Cretaceous. The other forty six spores discarded were Late Cretaceous in age and older or had species designations. The geology of this part of the Offshore Site is known to be a Late Cretaceous, early drift stage with Africa and South America slowly drifting farther apart from each other. As with the previous zones, there are no indicator species present to isolate this zone specifically to the middle and late parts of the Coniacian Stage. The microflora gives very little indication as to the age of this zone, however taking the geology into consideration; a Late Cretaceous age for Zone CIV has been concluded.</td></tr>
</table>

Table 6.6. The biostratigraphy of Zone CIV, Offshore Site C-B1.

Zone CIV of this site is Late Cretaceous in age and specified by the Petroleum Agency, SA as the middle to the late part of the Coniacian Stage. The palynomorphs in Table 6.6 reflect an entrance level age requirement for the Late Cretaceous.

As with Zone CIII, there are no indicator species present to isolate this zone specifically to the middle or late part of the Coniacian Stage. Five species disappeared at the start of the middle part of the Coniacian Stage and two at the close of the middle part of the Coniacian Stage.

None of these species could indicate an age for this zone. The entrance level requirements of the palynomorphs, suggest a Late Cretaceous age for Zone CIV.

6.2.6 STRATIGRAPHIC DISTRIBUTION WITHIN SUBZONE CV - A OF OFFSHORE SITE C-B1

The geology of this part of Offshore Site C-B1 is known to be Late Cretaceous in age and specified by the Petroleum Agency, SA as the late part of the Coniacian Stage to Campanian in age.

There are again no indicator species present to isolate this zone specifically to the Late Coniacian or Campanian stages. Nine species disappeared at the start of this late part of the Coniacian Stage and none of these species could indicate an age for this period. A further 20 species disappeared at the start of the Cenomanian Stage and again none could indicate an age for this zone either. *Andreisporis mariea, Buttinia andreevii, Buxaceaepollenites cainozoicus, Constantinisporis jacquei*, *Dorreenipites* sp. and *Tetracolporites ixerboides*, have an entrance level age from the Late Cretaceous to Tertiary periods. *Dorreenipites* sp. is the only pollen grain with a sp. designation to be included into the entrance level requirements as this species in general is known to be Late Cretaceous in age. *Buttinia andreevii* and *Constantinisporis cainozoicus* are not indicator species but their presence does confine this zone specifically to the Late Cretaceous Period. The entrance level age requirements (Table 6.7) of the palynomorphs present, suggest a general Late Cretaceous age for Subzone CV - A.

SUBZONE CV - A, THE MIDDLE OF THE LATE CONIACIAN TO START OF THE CAMPANIAN STAGE		
GEOLOGY:	**PALYNOMORPHS PRESENT:**	**ABUNDANCE:**
The Late Cretaceous of this South Atlantic middle drift region represented a deep marginal marine facies.	Land derived pollen and spores occur in association with scattered occurrences of marine dinoflagellates.	56 species are present: 14 species of pollen grains 42 species of trilete spores
ENTRANCE LEVEL SPECIES: Species with Late Cretaceous or younger entrance levels are listed below: *Andreisporis mariae* – Late Cretaceous (Senonian) *Buttinia andreevii* – K / T boundary *Buxaceaepollenites cainozoicus* – Late Cretaceous *Constantinisporis jacquei* – Late Cretaceous (Senonian) *Dorreenipites* sp. – Late Cretaceous / Tertiary *Tetracolporites ixerboides* – Tertiary *Divisisporites euskirchenensis* – Early Tertiary *Gemmatriletes morolus* – Late Cretaceous *Mediobaculatisporites mediobaculatus* – Tertiary *Undulatitriletes hertensis* – Tertiary *Undulatisporites microcutis* – Early Tertiary		
BIOSTRATIGRAPHIC CONCLUSION: Five of the fourteen pollen grains are long-ranging and have been reported in strata older than the Late Cretaceous by many researchers. Three pollen grains have species designations and therefore do not have a defining age but *Andreisporis mariea, Buttinia andreevii, Buxaceaepollenites cainozoicus, Constantinisporis jacquei*, *Dorreenipites* sp. and *Tetracolporites ixerboides*, have an entrance level age of Late Cretaceous to Tertiary. *Dorreenipites* sp. is the only pollen grain with a sp. designation to be included into the entrance level requirements as this species in general is known to be Late Cretaceous in age. Five of the fourty two species of spores had the entrance level requirements to classify this zone as Late Cretaceous. The other thirty seven spores discarded were Late Cretaceous in age and older or had species designations. The geology of this part of the Offshore Site is known to be a Late Cretaceous, middle drift phase represented by a deep marginal marine facies. *Buttinia andreevii* and *Constantinisporis cainozoicus* are not indicator species but their presence does confine this zone specifically to the Late Cretaceous Period. Taking the geology and the microflora into consideration, a Late Cretaceous age for Subzone CV - A has been concluded.		

Table 6.7. The biostratigraphy of Subzone CV - A, Offshore Site C-B1.

6.2.7 STRATIGRAPHIC DISTRIBUTION WITHIN SUBZONE CV - B OF OFFSHORE SITE C-B1

Subzone CV - B is Late Cretaceous in age and specified by the Petroleum Agency, SA as Campanian in age.

<table>
<tr><th colspan="3">SUBZONE CV - B, THE LATE CAMPANIAN STAGE</th></tr>
<tr><td>GEOLOGY:
The Late Cretaceous of this South Atlantic middle drift region represented a deep marginal marine facies.</td><td>PALYNOMORPHS PRESENT:
Land derived pollen and spores occur in association with scattered occurrences of marine dinoflagellates.</td><td>ABUNDANCE:
25 species are present:
10 species of pollen grains
35 species of trilete spores</td></tr>
<tr><td colspan="3">ENTRANCE LEVEL SPECIES:
Species with Late Cretaceous or younger entrance levels are listed below:

Andreisporis mariae – Late Cretaceous (Senonian)
Buttinia andreevii – K / T boundary
Oribiculapollis globosus – Late Cretaceous
Tetracolporites ixerboides – Tertiary
Victorisporis robertii – Late Cretaceous (Senonian)
Undulatisporites microcutis – Early Tertiary</td></tr>
<tr><td colspan="3">BIOSTRATIGRAPHIC CONCLUSION:

Three of the ten pollen grains are long-ranging and have been reported in strata older than the Late Cretaceous. There are two pollen grains have species designations and therefore do not have a defining age but Andreisporis mariea, Buttinia andreevii, Oribiculapollis globosus, Tetracolporites ixerboides and Victorisporis robertii have an entrance level age of Late Cretaceous to Tertiary. Only one of the twenty five species of spores had the entrance level requirements to classify this zone as Late Cretaceous. The other twenty four spores discarded were Early Cretaceous in age and older or had species designations. The geology of the area is known to be a Late Cretaceous, middle drift phase representing a deep marginal marine facies. There are no indicator species present to isolate this zone to the Campanian however the presence of Andreisporis mariea, Buttinia andreevii and Victorisporis robertii suggest that the Late Cretaceous is coming to a close. The geology and the Late Cretaceous microflora suggest a Late Cretaceous age for Subzone CV - B.</td></tr>
</table>

Table 6.8. The biostratigraphy of Subzone CV - B, Offshore Site C-B1.

There are no indicator species present to isolate this zone specifically to the Campanian Stage however the presence of *Andreisporis mariea, Buttinia andreevii* and *Victorisporis robertii,* all palm pollen reflects a change in the flora suggesting that the Late Cretaceous period was coming to a close. *Andreisporis mariea, Buttinia andreevii, Oribiculapollis globosus*, *Tetracolporites ixerboides* and *Victorisporis robertii* have an entrance level age (Table 6.8) from the Late Cretaceous to the Tertiary Period. The geology of the area is known to be a Late Cretaceous, middle drift phase and the Late Cretaceous microflora suggest a Late Cretaceous age for Subzone CV – B.

6.3 BIOSTRATIGRAPHIC DISTRIBUTION FOR OFFSHORE SITE O-A1

Tables 6.10. – 6. 14 have been included to help simplify the description and discussion of the relevant zones in Figure 6.4. Each zone is labeled, however due to the limited space on the biostratigraphic distribution diagram, a table (Table 6.9) has been constructed listing the zone and it's relevant age range.

ZONE / SUBZONE	AGE RANGE
ZONE OI	Barremian to early part of the Aptian stages.
ZONE OII	Early Aptian to end of Early Albian / start of Turonian stages.
ZONE OIII	Early Albian / start of Turonian stages to end of the middle Coniacian Stage.
ZONE OIV	Middle Coniacian Stage to middle of the Late Coniacian Stage.
ZONE OV	Late Coniacian Stage to the end of the Early Santonian Stage.

Table 6.9. A quick reference guide for zones / subzones and their relevant ages.

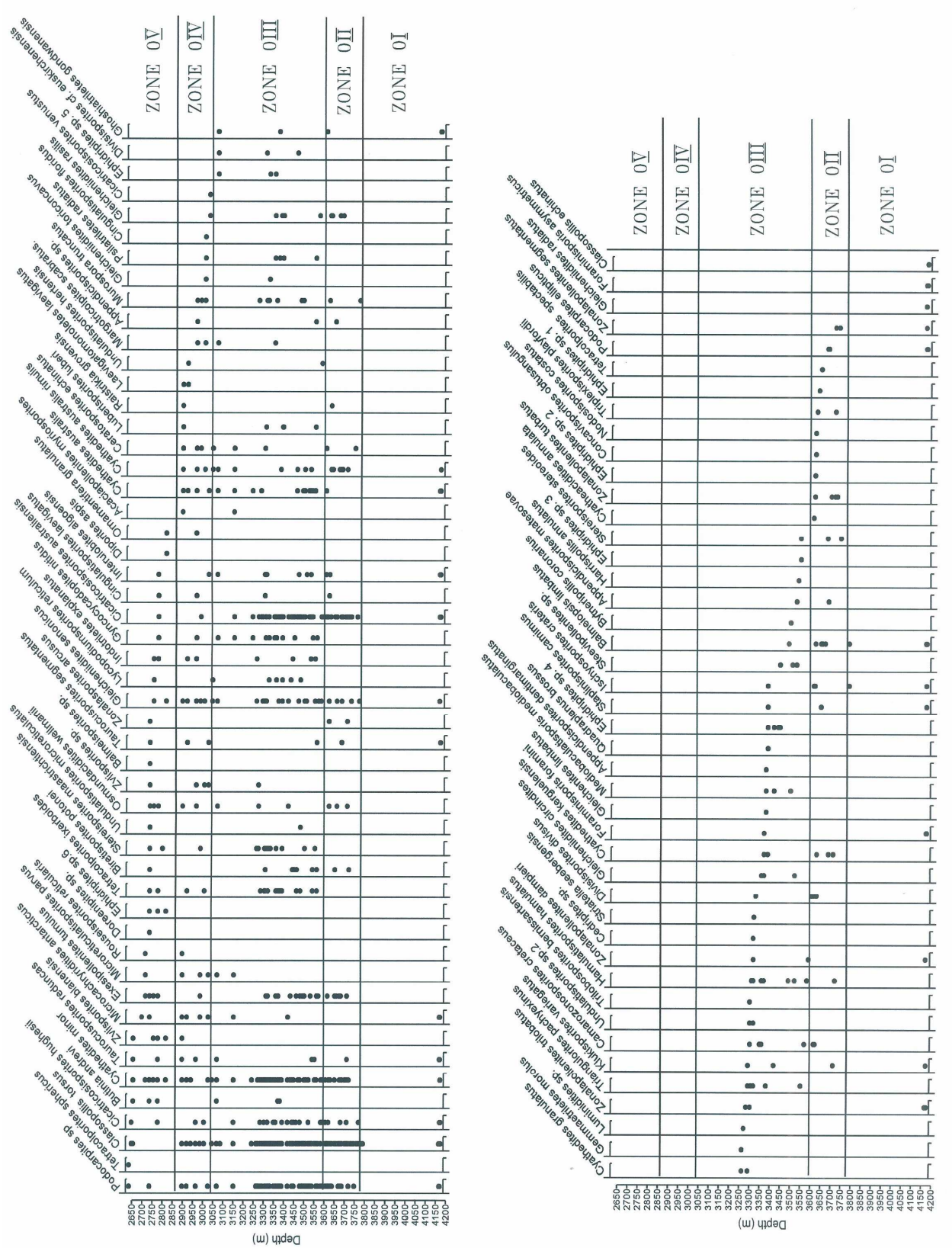


Figure 6.4. Age and correlation of microflora in Offshore Site O-A1.

6.3.1 STRATIGRAPHIC DISTRIBUTION WITHIN ZONE OI OF OFFSHORE SITE O-A1

Zone OI is Early Cretaceous in age due to the known geology of the region and specified by the Petroleum Agency, SA, as Barremian to Aptian in age.

<table>
<tr><th colspan="3">ZONE OI, THE BARREMIAN TO APTIAN STAGE</th></tr>
<tr><td>GEOLOGY:
The Early Cretaceous of this South Atlantic rift region represents an early rift environment.</td><td>PALYNOMORPHS PRESENT:
Pollen and spores are abundant. No microplankton occurs in this zone.</td><td>ABUNDANCE:
25 species are present:
9 species of pollen grains
16 species of trilete spores</td></tr>
<tr><td colspan="3">ENTRANCE LEVEL SPECIES:
Species with Early Cretaceous or younger entrance levels are listed below:
Cicatricosisporites australiensis – Early Cretaceous
Cicatricosisporites hughesii – Early Cretaceous
Foraminisporis asymetricus – Early Cretaceous
Foraminisporis foraminis – Early Cretaceous
Gleicheniidites radiatus – Early Cretaceous (Aptian)
Interulobites algoensis – Early Cretaceous
Ischyosporites crateris – Early Cretaceous
Taurocusporites reduncus – Early Cretaceous
Taurocusporites segmentatus - Early Cretaceous</td></tr>
<tr><td colspan="3">BIOSTRATIGRAPHIC CONCLUSION:
Eight of the nine pollen grain species are long-ranging and have been reported in strata older than the Barremian by many researchers. The other one pollen grain has a species designation and therefore does not have a defining age. Nine of the sixteen species of spores had the entrance level requirements to classify this zone as Early Cretaceous. The other seven spores discarded were either Jurassic in age or older. The geology of the area was also taken into consideration as this part of the Offshore Site is known to represent an Early Cretaceous early rift environment. There are no indicator species present to isolate this zone specifically to the Barremian Stage however Gleicheniidites radiatus predominantly occurs in Aptian deposits.</td></tr>
</table>

Table 6.10. The biostratigraphy of Zone OI, Offshore Site O-A1.

The palynomorphs included in Table 6.10 have the entrance level age requirements for the Early Cretaceous and therefore a generalized age of the Early Cretaceous can be given to this zone. Three species disappear at the start of this zone (see Figure 6.4) and of these *Gleicheniidites radiatus* is known to be make its first appearances during the Aptian Stage (Krutzsch, 1959) while *Foraminisporis asymetricus* also an Early Cretaceous species disappears during the Aptian Stage. Taking the geology and the microflora into consideration, this zone cannot specifically be isolated to the Barremian Stage but the Aptian Stage can be supported.

6.3.2 STRATIGRAPHIC DISTRIBUTION WITHIN ZONE OII OF OFFSHORE SITE O-A1

This part of Offshore Site O-A1 is known to be Early Cretaceous in age due to the known geology of the region and specified by the Petroleum Agency, SA, Zone OII is Aptian to Albian in age. The palynomorphs included in Table 6.11 have the entrance level age requirements for the Early Cretaceous and therefore a generalized age of the Early Cretaceous can be given to this zone.

The Aptian regressive event occurred specifically between 3793 m – 3791.5 m with the deposition of a 1.5 m thick limestone interval (See Chapter 5). This event brought with it a drop in sea level.

Ten species disappeared in this zone (see Figure 6.4) and do not reappear again. Of these ten species *Gleicheniidites radiatus* appears to have died out at the end of the Aptian Stage having made its first appearance at the beginning of the same period. This species reflects the same behaviour as in Offshore Site C-B1's Zone OII thereby supporting the suggestion that this species could well be an indicator species for the Aptian Stage. Numerous species disappeared during the Aptian – Albian Stage of Zone OII that did not reappear again. Among them were *Nodosisporites costatus* and *Zonalapollenites turbatus*. These two species cannot affirm a specified age but they can support an Early Cretaceous age for this zone.

ZONE OII, THE APTIAN TO ALBIAN STAGES		
GEOLOGY: The Early Cretaceous of this South Atlantic rift region represents an early rift environment.	**PALYNOMORPHS PRESENT:** Land derived pollen and spores occur in association with scattered occurrences of marine dinoflagellates.	**ABUNDANCE:** 42 species are present: 10 species of pollen grains 32 species of trilete spores

ENTRANCE LEVEL SPECIES: Species with Early Cretaceous or younger entrance levels are listed below:	*Cingulatisporites levispecoisus* – Early Cretaceous *Concavisporites obtusangulus* – Early Tertiary *Divisisporites divisus* – Early Tertiary *Gleicheniidites rasilis* – Early Cretaceous - Aptian *Hamulatisporites hamulatus* – Early Cretaceous *Interulobites algoensis* – Early Cretaceous *Ischyosporites crateris* – Early Cretaceous *Nodosisporites costatus* – Early Cretaceous *Stereisporites stereoides* – Tertiary *Taurocusporites reduncus* – Early Cretaceous *Taurocusporites segmentatus* – Early Cretaceous
Tertracolporites spectabilis – Tertiary *Appendicisporites matesovae* – Early Cretaceous *Appendicisporites tricorinatatus* – Early Cretaceous *Biretisporites potoniaei* – Early Cretaceous *Camarozonosporites cretaceus* – Cretaceous – Tertiary *Ceratosporites equalis* – Early Cretaceous *Cicatricosisporites australiensis* – Early Cretaceous *Cicatricosisporites hughesii* – Early Cretaceous	

BIOSTRATIGRAPHIC CONCLUSION:

Six of the ten pollen grains are long-ranging and have been reported in strata older than the Barremian. Three pollen grains have species designations and therefore do not have a defining age but *Tetracolporites spectabilis* has an entrance level of Tertiary age. Eighteen of the thirty two species of spores had the entrance level requirements to classify this zone as Early Cretaceous. The other fourteen spores discarded were Jurassic in age and older or had species designations. The geology of the area was also taken into consideration, as this part of the Offshore Site is known to represent the Early Cretaceous late rifting phase. There are no indicator species present to isolate this zone specifically to the Aptian and Albian stages however, there is one species of *Gleicheniidites* that is known to be make their first appearances during the Aptian Stage. Taking the geology and the microflora into consideration, an Early Cretaceous age for Zone OII has been concluded.

Table 6.11. The biostratigraphy of Zone OII, Offshore Site O-A1.

6.3.3 STRATIGRAPHIC DISTRIBUTION WITHIN ZONE OIII OF OFFSHORE SITE O-A1

The Cenomanian Stage was not preserved at this Offshore Site possibly due to the Cenomanian

<table>
<tr><th colspan="3">ZONE OIII, THE TURONIAN TO MIDDLE PART OF THE CONIATIAN STAGE</th></tr>
<tr><td>GEOLOGY:
This zone represents the onset of drift i.e. the early drift phase.</td><td>PALYNOMORPHS PRESENT:
Land derived pollen and spores occur in association with scattered occurrences of marine dinoflagellates.</td><td>ABUNDANCE:
47 species are present:
22 species of pollen grains
69 species of trilete spores</td></tr>
<tr><td colspan="3">ENTRANCE LEVEL SPECIES:
Species with Late Cretaceous or younger entrance levels are listed below:
Acaciapollenites myriosporites – Late Cretaceous to Tertiary
Bytneripollis coronarius – Early Tertiary
Buttinia andreevii- Late Cretaceous
Harrisipollenites annulatus – Tertiary
Quadraplanus brossus – Teriary
Tetracolporites ixerboides – Tertiary
Triangulorites pachyexinus – Tertiary

Divisisporites divisus – Early Tertiary
Divisisporites euskirchenensis – Early Tertiary
Foraminisporis foraminis – Tertiary
Gemmatriletes morolus – Late Cretaceous
Mediobaculatisporites mediobaculatus – Tertiary
Undulatitriletes hertensis – Early Tertiary
Undulatisporites microcutis – Early Tertiary</td></tr>
<tr><td colspan="3">BIOSTRATIGRAPHIC CONCLUSION:
Five of the twenty two pollen grains are long-ranging and have been reported in strata older than the Barremian. The eight pollen grains have species designations and therefore do not have a defining age but seven pollen grains have an entrance level age of Late Cretaceous to middle Tertiary. Seven of the forty seven species of spores had the entrance level requirements to classify this zone as Late Cretaceous. The other forty spores discarded were Jurassic in age and older or had species designations. The geology of the area was also taken into account as this part of the Offshore Site is known to represent the start Late Cretaceous, late rift, early drift stage. There are no indicator species present to isolate this zone specifically from to the Turonian to middle Coniation stages. Taking the geology and the microflora into consideration, a Late Cretaceous age for Zone OIII has been concluded.</td></tr>
</table>

Table 6.12. The biostratigraphy of Zone OIII, Offshore Site O-A1.

regressive event.

The Petroleum Agency, SA has specified this zone as Turonian to early to middle parts of the Coniacian in age. The palynomorphs included in Table 6.12 have the entrance level age requirements for the Late Cretaceous and therefore a generalized age of the Late Cretaceous can be given to this zone.

A minor regressive event occurred during the Turonian Stage and this can be seen in the disappearance of six species, three of which are known Tertiary species (see Figure 6.4). *Balmeiopsis limbatus* disappeared at the start of the Coniacian Stage after the Turonian regressive event. A similar scenario occurred in Offshore Site C-B1 when *Balmeiopsis limbatus* disappeared at the start of the Albian Stage after the Aptian regression. In both cases *Balmeiopsis limbatus* disappears at the end of a regressive sea level phase.

Twenty five species disappear in stages during and at the close of the early part of the Coniacian Stage however none of these species could be isolated (first or last appearance) to this period. Together with the Turonian regression and the entrance level age requirements of the palynomorphs, a Late Cretaceous age for Zone OIII is concluded.

6.3.4 STRATIGRAPHIC DISTRIBUTION WITHIN ZONE OIV OF OFFSHORE SITE O-A1

The geology of this part of Offshore Site O-A1 is Late Cretaceous in age and specified by the Petroleum Agency, SA as the middle to the late part of the Coniacian Stage. Sixteen species disappeared in phases during Zone OIV (see Figure 6.4) and none of them could give an indication as to an age for this zone or isolate this zone specifically to the middle or late parts of the Coniacian Stage. *Acaciapollenites myriosporites* and *Tetracolporites ixerboides* have an entrance level age (Table 6.13) of Late Cretaceous to Tertiary periods so taking the geology into consideration; a Late Cretaceous age for Zone OIV has been concluded.

ZONE OIV, THE MIDDLE PART OF THE CONIACIAN TO THE MIDDLE PART OF THE LATE CONIACIAN STAGE		
GEOLOGY: This zone represents middle drift phases with Africa and South America effectively separated from each other and drifting further apart.	**PALYNOMORPHS PRESENT:** Land derived pollen and spores occur in association with scattered occurrences of marine dinoflagellates.	**ABUNDANCE:** 38 species are present: 8 species of pollen grains 30 species of trilete spores
ENTRANCE LEVEL SPECIES: Species with Late Cretaceous or younger entrance levels are listed below: *Acaciapollenites myriosporites* – Late Cretaceous to Tertiary *Tetracolporites ixerboides* – Tertiary *Stereisporites electoides* – Tertiary *Undulatitriletes hertensis* – Early Tertiary		
BIOSTRATIGRAPHIC CONCLUSION: Four of the eight pollen grains are long-ranging and have been reported in strata older than the Late Cretaceous by many researchers. There two pollen grains that have species designations and therefore do not have a defining age but *Acaciapollenites myriosporites* and *Tetracolporites ixerboides* has an entrance level age of Late Cretaceous to Tertiary. Only two of the thirty eight species of spores had the entrance level requirements to classify this zone as possibly Late Cretaceous. The other thirty six spores discarded were Late Cretaceous in age and older or had species designations. The geology of the area was also taken into consideration as this part of the offshore site is known to be Late Cretaceous, early drift stage with Africa and South America slowly drifting farther apart from each other. There are no indicator species present to isolate this zone specifically to the middle Coniacian and late part of the Coniacian stages. Taking the geology into consideration a Late Cretaceous age for Zone OIV has been concluded however the microflora again gives very little indication as to the age.		

Table 6.13. The biostratigraphy of Zone OIV, Offshore Site O-A1.

6.3.5 STRATIGRAPHIC DISTRIBUTION WITHIN ZONE OV OF OFFSHORE SITE O-A1

Zone OV is known to be Late Cretaceous in age and specified by the Petroleum Agency, SA as the late part of the Coniacian to Santonian stages in age.

ZONE OV, THE MIDDLE PART OF THE LATE CONIACIAN TO THE SANTONIAN STAGES		
GEOLOGY: The Late Cretaceous of this South Atlantic middle drift region represented a deep marginal marine facies.	**PALYNOMORPHS PRESENT:** Land derived pollen and spores occur in association with scattered occurrences of marine dinoflagellates.	**ABUNDANCE:** 32 species are present: 10 species of pollen grains 22 species of trilete spores
ENTRANCE LEVEL SPECIES: Species with Late Cretaceous or younger entrance levels are listed below: *Buttinia andreevii* – K / T boundary *Diporites aspis* – Tertiary *Dorreenipites* sp. – Late Cretaceous / Tertiary *Tetracolporites ixerboides* – Tertiary *Stereisporites electoides* – Tertiary *Undulatisporites microcutis* – Early Tertiary		
BIOSTRATIGRAPHIC CONCLUSION: Four of the ten pollen grains are long-ranging and have been reported in strata older than the Late Cretaceous. There three pollen grains have species designations and therefore do not have a defining age but *Buttinia andreevii, Diporites aspis*, *Dorreenipites* sp. and *Tetracolporites ixerboides*, have an entrance level age of Late Cretaceous to Tertiary. *Dorreenipites* sp. is the only pollen grain with a sp. designation to be included into the entrance level requirements as the species in general is known to be Late Cretaceous in age. Two of the thirty two species of spores had the entrance level requirements to classify this zone as Late Cretaceous. The other thirty spores discarded were Late Cretaceous in age and older or had species designations. The geology of this Offshore Site is known to be Late Cretaceous, middle drift phase in age. As with the other zones, there are no indicator species present to isolate this zone specifically to the Turonian and middle Coniacian stages. Taking the geology into consideration, a Late Cretaceous age for Zone OV has been concluded however the microflora gives very little indication as to age and could suggest a much younger age.		

Table 6.14. The biostratigraphy of Zone OV, Offshore Site O-A1.

Twenty species disappeared at the end of the late part of the Coniacian Stage. As with the other zones, none of them could give an indication as to an age for this zone or isolate this zone specifically to the late part of the Coniacian Stage.

Dorreenipites sp. and *Diporites aspis* were two of the twenty species that did not cross over into the Santonian Stage and *Dorreenipites* sp. is the only pollen grain with a sp. designation to be included into the entrance level requirements (Table 6. 14) as this species in general is known to be Late Cretaceous in age.

Buttinia andreevii and *Tetracolporites ixerboides*, have an entrance level age of Late Cretaceous to Tertiary in age and can be found in the Santonian Stage however as with the late part of the Coniacian Stage, there are no indicator species present to isolate this zone specifically to the Santonian Stage either. Taking the geology into consideration, a Late Cretaceous age for Zone OV has been concluded however the microflora gives very little indication as to age and could suggest a much younger period.