24. PRELIMINARY PALYNOCOLOGICAL RESULTS: SITE 361, LEG 40, DEEP SEA DRILLING PROJECT

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ABSTRACT

Site 361 lies about 180 miles west-southwest of Cape Town. A single hole drilled to 1314 meters (subbottom) intersected a nearly continuous sequence of sediments ranging in age from Aptian to Eocene. Palynological studies were undertaken on 48 samples from the Cretaceous interval (Cores 12 to 48) and palynomorphs were recovered from nearly all the cores treated. The age indications generally support those based on foraminifers and coccoliths. Further information is provided on depositional environments, sediment provenance, and climate. The sapropelic lower lithological interval was probably deposited in a near-shore situation. The climate is interpreted as having been dry and the organic material was derived from a Classopollis-dominated local plant community. A benthic microfauna did exist, but the calcareous shells were mostly destroyed during early burial by acid interstitial fluids associated with the carbonaceous sediment. A diverse assemblage of dinoflagellate cysts with many cosmopolitan species indicates a free circulation of the surface water and a connection with the oceanic seas. The basin was probably silled, with restricted circulation of bottom water. The phytoplanktonic ratio increases markedly in the Upper Cretaceous as a result of the diminished supply of terrigenous spores and pollen, but species diversities remain constant. Bottom waters were generally well oxygenated. There is a suggestion of shallowing or a closer sediment source at three intervals within the Upper Cretaceous, where the delicate nature of the cuticular material suggests minimal transport of the plant debris. The climate at this time was probably wet and floras were dominated by ferns and angiosperms. Striated bisaccate pollen characteristic of the Permian and Triassic is persistently present in the Upper Cretaceous and points to a provenance in the southwestern Cape in South Africa. The sapropelic basal lithological unit has the appearance of a good petroleum source rock and is interpreted to be near the upper limit of thermal maturity necessary for the generation of hydrocarbons.

INTRODUCTION

This study was carried out as part of a shore-based palynological investigation. Samples were provided by Dr. W. Siesser of the University of Cape Town from all Cretaceous cores except Cores 26, 29, 38, 44, and 49. These were later supplied by Professor Bolli. Sample details are shown in Table 1 and the position of Site 361 is shown in Figure 1. Cores 12-27 are from lithologic Unit 6 of Site 361 (Chapter 2, this volume) and Cores 28-49 are from Unit 7.

Before palynological processing the samples were soaked in water to disaggregate them and washed onto a 150 mesh screen to remove any megaspores or microfaunal shells which might have been present. The minus 150 mesh sludge was then subjected to standard palynological processing. Slides were prepared of both unoxidized and stained oxidized organic residues.

Because the time available for study initially was short, this report was first prepared without taxonomic notes or photographic illustration, concentrating on providing information relevant to the geology of Site 361. To this end, comments were made where possible on the ideas presented by the shipboard party in the Leg 40 Hole Summary Book-material subsequently incorporated into Chapters 1 and 2 of this volume, and the initial report of the shipboard party. An extension of time allowed the inclusion, as an addendum, of taxonomic and descriptive notes and illustrations of the spores and pollen only. The dinoflagellates and acritarchs are described and illustrated by Davey (this volume).

The most important results and conclusions are displayed in Figure 2.

PALYNOCOLOGICAL RESULTS

Spores and Pollen

The main results are shown in Table 1, and in Figures 2 and 3. Miospore preservation is generally good,
although examples of radiate bacterial corrosion were seen in some Upper Cretaceous samples. Species diversities are low in the Lower Cretaceous with no sample yielding more than 30 species. In contrast, the Upper Cretaceous samples are much richer, with a maximum of 82 species in Core 19. This marked difference requires some explanation. The species diversity curve reflects the interaction of a number of elements such as climate, provenance, miospore preservation, sample yield, and so forth. However, we believe that climate and provenance are probably the most important. The low diversities could then be interpreted to reflect a harsh climate of some sort (cold or low rainfall) and/or a supply of spores and pollen from a restricted area or plant community. The low proportion of fern and fungal spores may indicate a dry climate, but may also simply reflect dilution by pollen from the dominant classopolis vegetation or a variety of other ecological factors. The Upper Cretaceous assemblages, on the other hand, with their much higher diversities, indicate a less harsh climate (warmer, and wetter?) and a source of spores and pollen from a much wider area including more diverse plant communities. These interpretations find support in the floral composition graph (Figure 2). A restricted provenance and a local plant community which supplied organic material to unit 7 are compatible with the great dominance of *Classopollis* in Cores 27 to 48: Harsh environments are characterized by adaptable species, which achieve dominance through lack of competition. Hughes (1973, p. 190) concluded that the plants producing *Classopollis* pollen were presumably coniferophytes and grew on the seaward margin of deltas, as mangrove plants do in the present time. There is some correlation between the species-diversity and the composition-of-organic-material graphs. Species diversities are highest in Cores 18, 19, and 20, where the detrital organic material is finest and most abraded, suggesting relatively long transport; it drops in Cores 17 and 13, and in Cores 21 and 24, where coarser material and more cuticular remains suggest closer source areas.

The dominance of *Classopollis* declines sharply within the Upper Cretaceous, and it becomes a minor element above the middle of the interval. *Classopollis classoides* types predominate in Unit 7, but in Unit 6 forms comparable with *C. perplexus* (Classopollis VI) similar to *C. perplexus* Boltenhagen, 1973, of the Cenomanian in Gabon is also present in Unit 6. Compared to the situation in the Agulhas bank wells, where *Inaperturopollenites* and *Araucariacites* pollen grains are common throughout the Lower Cretaceous (unpublished SOEKOR information), these

![Table 1: Details of Samples Processed, Site 361, Leg 40](image)

<table>
<thead>
<tr>
<th>SOEKOR Palynology Sample Number</th>
<th>Sample (Interval in cm)</th>
<th>Miospores Phyto-plankton</th>
<th>Microforaminifera</th>
<th>Megaspores Forams</th>
</tr>
</thead>
<tbody>
<tr>
<td>4977</td>
<td>12-3, 90-92</td>
<td>-</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4978</td>
<td>13-1, 123-125</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4979</td>
<td>14-2, 55-57</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4980</td>
<td>15-2, 19-21</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4981</td>
<td>15, CC</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4982</td>
<td>16-1, 33-33</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4983</td>
<td>17-2, 51-33</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4984</td>
<td>18-2, 140-141</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4985</td>
<td>19-2, 142-143</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4986</td>
<td>19-4, 91-92</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4987</td>
<td>20-2, 144-146</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4988</td>
<td>21-2, 131-133</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4989</td>
<td>22-2, 92-92</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4990</td>
<td>23-2, 61-64</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4991</td>
<td>24-2, 96-98</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4992</td>
<td>25-3, 94-97</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Note: - = Barren, + = Very poor to poor, ++ = Moderate, +++ = Good, F = Foraminifera, M = Megaspores. (Recovered by wet screening before processing.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
two genera are fairly rare at Site 361. As in described Australian floras, *I. limbatus* Balme, 1957, is restricted to the Lower Cretaceous (cf. Burger, 1973).

In the saccate flora mono- and bisaccates dominate in the Lower Cretaceous, while trisaccates become more important in the Upper Cretaceous. Many of the trilete fern spores in the Lower Cretaceous interval of Site 361 have also been recorded from Australia, but the important species on which the Australian zonations are based, are lacking. These include *Pilosisporites, Trilobosporites, Contignisporites*, etc. (Burger, 1973; Dettmann, 1963), which are present however in the Agulhas bank wells (unpublished SOEKOR information). Though few in numbers, many species of *Cicatricosisporites* and *Appendicisporites* are present at Site 361. There are few similarities with the described West African floras, but *Zlivisporites blanensis* Palet, 1961, recorded by Bollenhagen (1967) from Gabon, are present in the Senonian of Site 361.

The angiosperms appear very suddenly and in great numbers in Core 24 of lithological Unit 6. Contrary to the sequence of appearance in Australia (Dettmann,
Phytoplankton (dinoflagellate cysts and acritarchs)

Yields of phytoplankton are consistently much lower than of spores and pollen, but the degree of preservation is generally good. The percentage phytoplankton graph in Figure 2 shows persistent low ratios in the Lower Cretaceous, but a marked increase within the Upper Cretaceous. This pattern is in line with the idea expressed in Chapter 2 of this volume, that the supply of terrigenous material—spores and pollen—in this case—dwindled during the Late Cretaceous. It is probable, however, that the fall-off is due as much to the greater distance of transport to the depositional site as to reduction of relief in the provenance.

The persistent presence of phytoplankton confirms that sedimentation took place in a marine environment throughout the interval cored at Site 361; this is further supported by the presence in nearly all the samples of the acid-resistant chitinous linings of the initial chambers of benthic foraminifer (commonly referred to as “microforaminifers” after Wilson and Hoffmeister, 1952).

Acritarchs form an insignificant proportion of the assemblages. Crassospheera bella Singh, 1971, is rare but quite conspicuous in Unit 7 and Pterospermella spp. are common in this unit but was not recorded above Core 27. It would be interesting to know whether these palynomorphs are characteristic of the Unit 7 sort of depositional environment elsewhere in the world. Species of Cymatosphaera and Michystridium are both present in small numbers throughout Units 6 and 7.

The presence of the alga Botryococcus within the Late Cretaceous samples is interesting. It typically occurs in shallow, fresh- to brackish-water lakes and pans at the present day. It is most unlikely that it lived in the deep-water conditions of lithological Unit 6, and it was probably transported in with other land-derived organic material. For it to be so consistently represented, it must have been quite abundant in the source area. This could be tentatively taken to imply that the shores at the time were of fairly low relief and that there were extensive areas of brackish-to-fresh water marsh and shallow lakes supporting Botryococcus, which was periodically swept out to sea by floods. Palambages spp. were noted only in the Late Cretaceous (Cenomanian to Turonian?) in Cores 21 to 24. Davey (1970) has reported Palambages in the Alban and Cenomanian of Europe and North America.

Figure 2. Graphic display of main palynological results, Site 361.
PALYNOCOLOGICAL RESULTS, SITE 361

Figure 2. (Continued).
Figure 3. Spore and pollen range chart and species diversity graph, Site 361.
### Figure 3. (Continued)

<table>
<thead>
<tr>
<th>Palynological Results, Site 361</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Palynomorphs</strong></td>
</tr>
<tr>
<td>Cricocerospora opticus, Phillips, Felix 1971</td>
</tr>
<tr>
<td>Cussoerasthenes bertholletii Pocock 1964</td>
</tr>
<tr>
<td>Cystipollinicole cooksonii, (Bolle) Dettmann 1963</td>
</tr>
<tr>
<td>Deltioptilum pteropodes, Pocock 1969</td>
</tr>
<tr>
<td>Ceratidion saccharina, De Jersey</td>
</tr>
<tr>
<td>Neurospora truncata, (Griffiths) Paton 1956</td>
</tr>
<tr>
<td>Applicatipollidites crakewy, Pocock 1964</td>
</tr>
<tr>
<td>Equisetospora virgulatis, (Bolles) Dettmann 1963</td>
</tr>
<tr>
<td>Equisetospora exile, Henningsen 1971</td>
</tr>
<tr>
<td><strong>Liliaceae</strong></td>
</tr>
<tr>
<td>Liliaceae moschata, Singh 1971</td>
</tr>
<tr>
<td><strong>Lycopodium</strong></td>
</tr>
<tr>
<td>Lycopodium cordatum, Bolle 1958</td>
</tr>
<tr>
<td><strong>Ginkgo</strong></td>
</tr>
<tr>
<td>Ginkgo biloba, (L.) Gray 1956</td>
</tr>
<tr>
<td><strong>Cycadophyta</strong></td>
</tr>
<tr>
<td>Cycadophyta, (L.) Gray 1956</td>
</tr>
<tr>
<td><strong>Gymnosperms</strong></td>
</tr>
<tr>
<td>Taxodiaceae, (L.) Gray 1956</td>
</tr>
<tr>
<td><strong>Coniferopsida</strong></td>
</tr>
<tr>
<td>Pinaceae, (L.) Gray 1956</td>
</tr>
<tr>
<td><strong>Pteridophyta</strong></td>
</tr>
<tr>
<td>Pteridophyta, (L.) Gray 1956</td>
</tr>
<tr>
<td><strong>Ferns</strong></td>
</tr>
<tr>
<td>Pteridophyta, (L.) Gray 1956</td>
</tr>
</tbody>
</table>

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Only the more prominent dinoflagellate cyst species are shown on the accompanying range chart (Figure 4). They indicate clearly that the assemblages of both Upper and Lower Cretaceous are of a cosmopolitan nature and contain species which are familiar in Europe, Australia, and elsewhere in the world. This implies that the surface water of Units 6 and 7 was able to circulate freely and had an effective communication with the oceanic seas. Furthermore, the dinoflagellate species diversity graph (Figure 4) shows that many of the samples from the Lower Cretaceous interval have diversities equivalent to those of the Upper Cretaceous, which adds support to the idea of freely circulating surface water during the time Unit 7 was deposited.

As noted above, foraminifers are present in most cores. The most common forms show a simple coiled or trochoid chamber arrangement. Uniserial and biserial specimens were noted but are quite rare. Generic and specific identifications of the parent foraminifers are not possible. They are especially significant in those intervals where foraminifers were not reported in the shipboard record (Bolli and Ryan, 1975); it is likely that their original calcareous shells or carbonate-cemented shells were dissolved during early burial. We know of no record of microforaminifers from planktonic species. If this is correct then in Unit 7 they indicate the presence of a benthic microfauna, which in turn implies that the bottom environment was not "totally euxinic," as proposed in Chapter 2. The calcareous benthic foraminifers recovered by us from Cores 31 and 32 (see Table 1) confirm that a shelled benthos is present in at least some of the cores. This interpretation may have a bearing on the origin and deposition of the sediments: we are not entirely convinced that Unit 7 was deposited in particularly deep water. Within Unit 6 the microforaminifers simply record the wider presence of a deep-water microfauna presumably similar to that noted in the shipboard report for Cores 20 to 28.

Age

It has not been possible to arrive at an age subdivision that is consistent with the indications of the more important species of Site 361. The placing of many of the boundaries has therefore been rather arbitrary. Because of the paucity of reliable index spores and pollen, we have relied more heavily on the dinoflagellates to derive the breakdown shown in Figure 2. The dinoflagellate ranges shown in Figure 5 were obtained mainly from Williams (1974), Wiseman and Williams (1974), Davey and Verdier (1971, 1973, 1974) and Verdier (1975). The dinoflagellates were plotted against these ranges in the same order of appearance as detailed in Figure 4. By comparing Figures 4 and 5, it can be seen that the age indications of the species in any particular core sample are commonly in conflict. Nevertheless, although this makes the selection of stage boundaries arbitrary, it can be seen that the dinoflagellates support the age bracket given in the shipboard report and indicate sediments ranging in age from Aptian to Senonian. It has also been possible to make a broad correlation with the
Figure 4. Phytoplankton range chart and species diversity graph, Site 361.
petroleum exploration wells drilled on the Agulhas bank using unpublished SOEKOR information and approximately the same time range is indicated. (Age conclusions in the Agulhas bank wells are based on ostracode and foraminiferal evidence.) Three aspects call for discussion; these are the age of Unit 7, in particular its lowest part, the boundary of the Upper and Lower Cretaceous, and the age of the youngest Cretaceous sediments.

The presence of the following dinoflagellates supports the Aptian-Albian assignment of Unit 7 (see Figures 4 and 5):

Meiourogonyaulax stoveri—Pre-Cretaceous to Lower Aptian.
Dingodinium alberti—Mid-Hauterivian to Lower Aptian.
Tanyosphaeridium sp. (Singh, 1971)—Albian.
Pareodinia ceratophora—Pre-Cretaceous to Albian.
Dingodinium cerviculum—Barremian to Albian (shorter range of Wiseman and Williams, 1974).
Chlamydophorella nyei—Aptian to lower Turonian.
Systematophora schindewolfi—Barremian to Aptian.
Diconodinium glabrum—Upper Albian to Cenomanian.
Muderongia staurota of upper Hauterivian to upper Barremian age could be cited in support of the presence of upper Barremian but as it first occurs some distance above the bottom of the hole in association with a typical Aptian assemblage, it seems more likely that its range extends into the Aptian and even higher. There is some support for a division between Aptian and Albian in the vicinity of Cores 36 to 32 but lack of agreement of age ranges precludes allocation of a firm boundary. Last appearances of Systematophora schindewolfi, Meiourogonyaulax stoveri, and Dingodinium alberti and first appearances of Achomosphaera ramulifera and Chlamydophorella nyei suggest that the lower part of Unit 7 is Aptian. First appearances of Achomosphaera sagena and Diconodinium glabrum can be cited in support of an Albian age for the upper part of Unit 7.

There is a profound change in the composition of the flora between Cores 27 and 24. Because of the lack of palynological information from Cores 26 and 25 it seemed best to adopt the position of the Upper-Lower Cretaceous boundary shown by Bolli et al. (1975, p. 24) just below Core 24. Unfortunately the palynology supplies little definitive information. Simple reticulate tricolpate and trichotomosulcate angiosperm pollen makes its first appearance in the international record in about mid-Albian time. Its abrupt appearance in Core 24 suggests that the sediments are younger than upper Albian. The international first appearance of the
phoridium alatum
is upper Albian but at Site 361 where
Assessment of Organic Residue
same situation may apply at Site 361.
Core 27 suggests a greater similarity with the Unit 7
proportions of sapropel. The floral composition of
and relatively high proportions of lignite. The reducing
oxygenated—samples contained much less sapropel
tions; the siltier or sandier—and presumably better
the components classified according to the categories
organic residue of each sample has been examined and
attempt to distinguish stage boundaries within the
Upper Cretaceous interval on the information
available. There is no suggestion of any erosional or
depositional gap in the record and the polyplankton
provide support for the Cenomanian to Maestrichtian
allocation of Bolli et al. (1975). It is possible that a part
of the Maestrichtian is missing. In wells drilled on the
Agulhas bank, microfaunal information suggests a
widespread regression within the upper Maestrichtian,
and there seems to be a distinct but minor
unconformity at the top of the stage (McLachlan et al.,
in press). The depositional environment of Core 13 is
interpreted here as being significantly nearer source and
perhaps shallower than that of the rest of Unit 6, so the
same situation may apply at Site 361.

Assessment of Organic Residue
For this study only slides of unoxidized unstained
residue were used. Results are shown in Figure 2. The organic residue of each sample has been examined and
the components classified according to the categories
used by Correia (1971, p. 610), with slight modification viz.
MOC—Amorphous or colloidal sapropelic material.
MOV—Cuticular plant tissue, including spores,
pollen, fungi, phytoplankton.
MOT—Plant tracheid or other dense structured land
plant material, usually of a dark orange or brown color.
MOL—Apparently structureless lignitic material;
this includes micrinite, fusainite, and mineral charcoal.
The shaly samples of lithological Unit 7 yielded very
high proportions of sapropelic organic material,
indicating strongly reducing bottom sediment conditions;
the siltier or sandier—and presumably better
oxidated—samples contained much less sapropel
and relatively high proportions of lignite. The reducing
bottom conditions seem to have persisted through into
Unit 6, as Cores 27, 24, 23, and 22 all contain small
proportions of sapropel. The floral composition of
Core 27 suggests a greater similarity with the Unit 7
samples than with those of Unit 6. The increase in
lignitic material upward into Unit 6, indicates increasingly oxidated conditions, since lignite resists
destruction by oxidation more effectively than any of
the other types of organic material.
The average size of the detrital particles of organic
material shows some interesting trends (Figure 2).
Within lithological Unit 7 the material is relatively
course (>100 µm), implying that it has not been
subjected to much breakage or abrasion during
transport; it probably accumulated fairly near source.
On the other hand, the particle size is generally fine
within Unit 6 (<40µm); tracheid and lignitic fragments
are usually quite well rounded and are interpreted to
have been abraded during transport. This is compat-
ible with the deep-water distal depositional environ-
ment postulated in the shipboard report. There are
exceptions to this pattern. Core 23 has relatively
carser detrital organic material and a reduced phyto-
plankton content, Botryococcus is present, and the
content of fungal spores is relatively high. We interpret
this to record a regression with a (?) shallower water
depth and a reduction in transport distance. A similar
situation is indicated by the sample from Core 17.
Results from Core 13 are even more striking; the
residue contains a relatively large proportion of plant
cuticle, and spore with numbers of spores still in
place are conspicuous, together with a variety of other
delicate cuticular material. It is difficult to reconcile
these features and the information given in the section
above dealing with age, with the deep-water deposi-
tional environment suggested in the shipboard report
and in Bolli et al. (1975); we prefer to visualize a quiet,
shallow-water, near-shore environment.

A further application of this study is the assessment
of the potential of the sediments as petroleum source
rocks, using the techniques outlined by Correia (1971)
and others. Assuming a correspondingly high total
organic content, which seems reasonable from the
shipboard report, the high sapropel (MOC) content of
the 300-meter-thick shales of Unit 7 indicates a good
oil-generating potential. The color of the organic
material can be used to estimate the maximum
temperature to which the sediments have been
subjected and hence the “maturity” of the source rocks
(Correia, 1971); with increasing temperatures, volatile
components are progressively lost, resulting in an
increase in the carbon content of the material and a
corresponding darkening of color. We have used the
five-step scale of Correia (1971, table III), which
follows the changing color of spores, pollen, and other
organic material from pale translucent yellow, through
orange and brown to black. The scale units are referred
to here as “thermal alteration indices” or TAI s. The
results for Site 361 are shown in Figure 2. The highest
sample (Core 13) is barely altered; spores, pollen, and
phytoplankton remain generally pale yellow to yellow
and translucent down to the top of Unit 7, where some
darkening becomes apparent. Only the last 50 meters of
the unit is approaching the upper limit at which oil
might have been generated (TAI 2.5). This lithological
unit is said in the shipboard report to thicken shore-
wards. Where it is more deeply buried (± 500 m more)
and thicker, it could have acted as a significant
petroleum source rock.

An interesting feature concerning the color of the
miospores is the presence in Unit 7 of darkened spores and pollen with TAI s ranging from 2.5 (orange) to 4
(brown-black). Indentifiable specimens belong to the
same species as their pale in situ equivalents in the same
slides. No darkened phytoplankton was observed, so
the possibility of carboniation by accidental
overheating during laboratory processing can be
discounted. The fact that the darkened miospores
belong to the same species as the paler material in the
same slides also refutes the possibility of it being
reworked older Cretaceous material. It is tentatively
suggested that the darker miospores are the result of
forest fires. This would account for the variable
darkening, the common speciation, and the lack of
darkened phytoplankton. Dark, opaque yellow-orange (TAI 3.00-3.5) generally distinctly marked, striated bissaccate pollen grains were detected within Unit 6 samples (Figure 2); they probably derive from the sediments in the Karoo basin in South Africa (Figure 1). The organic material in the lower Permian Dwyka and Ecca Groups in the southern half of the basin has everywhere been strongly carbonized (brown-black to black, TAI 4a-5) and the same situation holds for the southwestern part of the Kalahari Karoo basin (personal observation). The color of the striated bissaccates in the Site 361 sediments indicates that they originated from sediments that were not strongly heated as a result of dolerite intrusion or deep burial. They are equivalent in color to pollen from the northern part of the Karoo basin which is estimated to have been buried not deeper than 1500 to 2000 meters. The source of the bisaccates was probably carbonaceous facies of Permian to Triassic age in the southwestern part of the Kalahari Karoo basin in South Africa.

ADDENDUM

Notes on spores and pollen

A list of the spores and pollen recorded can be found in the range chart on Figure 3. The absence of adequately preserved specimens for photography prevented the illustration of some species. Descriptive or taxonomic notes are only given in a few cases as the majority of the species accord well with the descriptions in the literature.

Classopollis spp.

Because of the difficulties involved, no attempt was made to speciate Classopollis, though several species are represented. For convenience the following broad grouping was used.

Classopollis I C. meyeriana-type. Smooth, solid appearance with no or only minor infrastructure. 23-38 µm diameter.

Classopollis III C. classoides-type. With conspicuous infrastructure and prominent striae near the equator. 25-35 µm diameter.

Classopollis IV Much like C. III but with less clear structure and generally smaller. 22-32 µm diameter.

Classopollis V Very fine infrastructure with radial folds round the periphery giving it a frill-like appearance. 28-30 µm diameter.


Inaperturopollenites spp.

The genus Inaperturopollenites was not speciated, but the following grouping based on a few outstanding characteristics, was used: Inaperturopollenites I & II Thin to medium wall with a thinned or thickened area in the center; smooth. Inaperturopollenites VI Subequatorial fold; smooth.

Inaperturopollenites VII Very thick wall; smooth. Inaperturopollenites VIII Granulate.

Densisporites

There may be more than one species of Densisporites, but because it is impossible to find sharp distinctions, all were retained under D. perinatus.

Trilobosporites and Contignisporites

Only a few specimens (one Contignisporites and two Trilobosporites) were found and thus were not regarded as stratigraphically significant.

?Tigrisporites

Although the specimen resembles Tigrisporites, no distal polar thickening can be seen as is required in the generic diagnosis.

Cyathidites sp.

This species possesses fine spines both proximally and distally. 24 µm in diameter.

Zlivisporites

Zlivisporites differs from Lycopodiumsporites in having a flange and a distal reticulum that does not continue onto the flange (Boltenhagen, 1967).

Cicatricosisporites

C. apiteretus differs from C australiensis only by having a solid area at the corners, whereas C. australiensis has a notched appearance.

Cicatricosisporites XIV

Amb triangular with rounded corners. Laesurae straight, with membranous lips and reaching 3/4 of spore radius. Distal face with ribs parallel to sides of amb, forming a triangle in the center. Proximally the ribs run subparallel to one laesura and oblique to the other one in each contact face, leaving a very small, smooth area next to the laesurae. The ribs are not straight but curve round the spore at the equator. At the corners the ribs fuse to form solid areas. Ribs 3 µm wide, canals 0.8 µm wide. A narrow groove runs down the center of each rib.

Dimensions: 56 (65) 80 µm (6 specimens).

Remarks: No fossil spore with the characteristic narrow groove in the center of the ribs could be found in the available literature, but a similar feature is seen in recent Mohria spp. (Welman, 1970).

Incertae sedis A

Outline circular. Porate. Inner body with scattered spines on proximal side. No stratification distinguishable in wall. Distal side psilate with heavy,
raised ornamentation. This consists of muri ~2µm in diameter forming an irregular curvimurate reticulum or terminating freely to form a maze. Round the equator it forms a perfect circle. The ornamentation is connected to the inner body by pillars of ~1 µm diameter. The muri are chagrinate and opaque light yellow.

Dimensions: 32 (34) 36 µm (5 specimens).

Angiosperms

The pollen grains were, where possible, given names of species already described in the literature, although the latter does not form a coherent system. Those that could not be identified were grouped together under Tricolpites spp. 1-11.

ACKNOWLEDGMENTS

We are indebted to Dr. W. Siesser who encouraged the study, provided the samples, and made available early results of the shipboard report and also to Professor H. Bolli who has been most generous with his assistance and advice. Material was processed in the SOEKOR laboratories, which are maintained at the Bernard Price Institute for Palaeontological Research. Dr. H. Winter, Dr. A. de Swardt, and Mr. S. van Wyk of Soekor and Dr. Ann Anderson of the Bernard Price Institute discussed various aspects of the work and critically reviewed the manuscript. Mr. I.K. McMillan of SOEKOR made identifications of foraminifers and microforaminifers.

The Management of SOEKOR is thanked for providing the time and facilities which were devoted to the study.

REFERENCES


Scott, L., in press. Palynology of Lower Cretaceous deposits from the Algoa basin (Republic of South Africa).
PLATE 1

All figures are magnified ×500. Additional information in following order: Negative Number; Core Number; Sample Number; Coordinates on Zeiss photomicroscope mechanical stage.

Figure 1  
_Cyathidites minor_ Couper, 1953, -22982; 24; 4991b.1; 116.5/16.5

Figure 2  
_Cyathidites sp._, -23048; 23; 4990b; 122/15.

Figure 3  
_Deltoidospora sp._, -22995; 18; 4984b; 120.6/20.

Figure 4  
_Deltoidospora hallii_ Miner, 1935, -23001; 19; 4986b; 103.5/10.5.

Figure 5  
_Biretisporites sp._, -23058; 23; 4990b; 115/22.3.

Figure 6  
_Psilatriletes radiatus_ Brenner, 1963, -23075; 24; 4991b; 78/22.5.

Figure 7  
_Concavisporites juriensis_ Balme, 1957, -23049; 23; 4990b; 76/15.

Figure 8  
_Stereisporites steroides_ (Potonié and Venitz) Martin and Rouse, 1966, -23072; 24; 4991b; 97/18.7.

Figure 9  
_Stereisporites antiquasporites_ (Wilson and Webster) Dettmann, 1963, -23055; 23; 4990b; 96/16.5.

Figure 10  
_Matonisporites equiexinous_ Couper, 1958, -23097; 40; 5011b; 117/21.

Figure 11  
_Todisporites minor_ Couper, 1958, -23054; 23; 4990b; 75/17.6.

Figure 12  
_Dictyophyllidites sp._, -23070; 24; 4991b; 78/16.7.

Figure 13  
_Dictyophyllidites mortoni_ (De Jersey) Playford and Dettmann, 1965, -23073; 19; 4986b; 98.3/17.5.

Figure 14  
_Unduatisporites sp._, -23005; 19; 4985b; 115.3/9.5.

Figure 15  
_Leptolepidites verrucatus_ Couper, 1953, -23003; 19; 4985b; 113.4/7.7.

Figure 16  
_Leptolepidites major_ Couper, 1958, -22976; 47; 5023b; 87/5.

Figure 17  
_Osmundacidites wellmanii_ Couper, 1958, -23114; 45; 5020a; 100/21.

Figure 18  
_Baculatisporites comaumensis_ (Cookson) Potonié, 1956, -23102; 41; 5014b; 115/9.5.

Figure 19  
_Verrucosisporites rotundus_ Singh, 1964, -23104; 43; 5016b; 90.5/14.

Figure 20  
_Verrucosisporites sp._, -22977; 41; 5012b; 92.8/14.

Figure 21  
_Ceratosporites equalis_ Cookson and Dettman, 1958, -23030; 20; 4987b; 95.4/20.5.

Figure 22  
_Ceratosporites helidonensis_ De Jersey, -23090; 35; 5002b; 106/19.

Figure 23  
_Nevesisporites vallatus_ De Jersey and Paten, 1964, -23107; 43; 5017b; 110/10.

Figure 24  
_Nevesisporites sp._ proximal view, -23026; 20; 4987b; 122/22.

Figure 25  
_Nevesisporites sp._ median view, -23027; 20; 4987b; 122/22.

Figure 26  
_Nevesisporites simiscalaris_ Phillips and Felix, 1971, -23040; 19; 4985b; 120/9.

Figure 27  
_Intervalobites sinusus_ (Brenner) Scott (in press) -23117; 43; 5018b; 82/9.4.

Figure 28  
_Intervalobites triangularis_ (Brenner) Phillips and Felix, 1971, -23083; 34; 5001b; 122.4/19.6.

Figure 29  
_Taurocusporites triangularis_ (Bolk) Stover, 1962, -23031; 18; 4984b; 79.4/16.

Figure 30  
_Taurocusporites reduncus_ (Bolk) Stover, 1962, -23113; 35; 5002b; 120/8.4.

Figure 31  
_Taurocusporites segmentatus_ Stover, 1962, -23101; 39; 5009b; 102.7/21.8.

Figure 32  
_Kuylisporites sp._ -23030; 20; 4987b; 99/17.7.

Figure 33  
_Gleicheniidites exelsus_ (Pierce) Norton, 1969, -23085; 31; 4997b; 79/22.7.

Figure 34  
_Gleicheniidites circinidites_ (Cookson) Dettmann, 1963, -23084; 13; 4978b; 124/11.1.

Figure 35  
_Gleicheniidites wonghaggienis_ (Cookson and Dettman) Dettmann, 1963, -23029; 20; 4987b; 98/21.

Figure 36  
_Matonisporites equiexinous_ Couper, 1958, -23001; 19; 4986b; 103.5/10.5.
All figures are magnified ×500. Additional information in following order: Negative Number; Core Number; Sample Number; Coordinates on Zeiss photomicroscope mechanical stage.

Figure 1  Lycopodiumsporites facetus Dettmann, 1963, -22989; 13; 4978b; 112/3.
Figure 2  Lycopodiumsporites reticulumsporites (Rouse) Dettmann, 1963, -22990; 13; 4978b; 122.5/7.7.
Figure 3  Lycopodiumsporites austroclavatidites (Cookson) Potonié, 1956, -23028; 20; 4987b; 120.4/22.4.
Figure 4  Lycopodiumsporites nodosus Dettmann, 1963, -23017; 20; 4987b; 113/20.8.
Figure 5  Lycopodiumsporites crassimacerius Hedlund, 1966, -23110; 41; 5014b; 82/12.7.
Figure 6  Klukisporites foveolatus Pocock, 1964, -23111; 36; 5006b.l; 88.7/9.7.
Figure 7  Zlivisporites blanensis Palct, 1961, -22993; 13; 4978b; 79.3/14.
Figure 8  ?Tigrisporites sp., -23052; 23; 4990b; 94/17.7.
Figure 9  Cicatricosisporites dorogensis Potonié and Gelletich emend Kedves, 1961, -23013; 13; 4978b; 116.7/19.
Figure 10 Cicatricosisporites intersectus Rouse, 1962, -23012; 20; 4987b.1; 90/14.
Figure 11 Cicatricosisporites pseudotripartitus (Bolk) Dettmann, 1963, -22997; 18; 4984b.1; 121.2/11.6.
Figure 12 Cicatricosisporites claricanalis Phillips and Felix, 1971, -23061; 24; 4991b; 85/4.3.
Figure 13 Cicatricosisporites strigosporites (Rouse) Kimyai, 1966, -23002; 19; 4986b; 92/10.5.
Figure 14 Cicatricosisporites australiensis (Cookson) Pocock, 1956, -23109; 19; 4986b; 88.5/22.
Figure 15 Cicatricosisporites venustus Deak, 1963, proximal view, -22999; 19; 4985b; 100.4/16.7.
Figure 16 Cicatricosisporites exiguus Herngreen, 1971, -23086; 35; 5002b.1; 94.6/22.6.
Figure 17 Cicatricosisporites apiteretus Phillips and Felix, 1971, -23094; 39; 5008b; 87/15.
Figure 18 Cicatricosisporites cuneiformis Pocock, 1965, -23080; 27; 4993b; 111.5/23.
Figure 19 Cicatricosisporites hughesi Dettman, 1963, -22986; 27; 4993b.1; 90/3.
Figure 20 Cicatricosisporites aralica (Bolkhovitina) Brenner, 1963, -23095; 39; 5008b; 90/19.8.
Figure 21 Cicatricosisporites carlylensis (Bolkhovitina) Brenner, 1963, -23095; 39; 5008b; 90/19.8.
Figure 22 Cicatricosisporites carlylensis Pocock, 1962, proximal view, -23033; 21; 4988a; 81.4/18.7.
Figure 23 Cicatricosisporites carlylensis Pocock, 1962, distal view, -23032; 21; 4988a; 81.4/18.7.
Figure 24 Cicatricosisporites XIV, -23020; 17; 4983a; 117/15.7.
Figure 25 Cicatricosisporites XIV, -23023; 13; 4978b; 88.5/12.6.
Figure 26 Appendicisporites degeneratus Thiergart, 1953, proximal view, -22984; 20; 4987b; 77.7/21.
Figure 27 Appendicisporites degeneratus Thiergart, 1953, distal view, -22983; 20; 4987b; 77.7/21.
PLATE 3

All figures are magnified ×500. Additional information in following order: Negative Number; Core Number; Sample Number; Coordinates on Zeiss photomicroscope mechanical stage.

Figure 1  Appendicisporites bilateralis Singh, 1971, -23015; 19; 4986b; 110.5/3.5.
Figure 2  Appendicisporites erdtmanii Pocock, 1964, -23069; 24; 4991b; 121/14.
Figure 3  Appendicisporites cristatus (Markova) Pocock, 1964, -23060; 24; 4991a; 93/16.
Figure 4  Appendicisporites jansonii Pocock, 1962, -23047; 21; 4988b; 103/22.3.
Figure 5  Appendicisporites crickmayii Pocock, 1964, -23088; 35; 5002b; 114/8.5.
Figure 6  Costatoperforosporites fistulosus Deak, 1962, -23068; 24; 4991b; 110/14.2.
Figure 7  Contignisporites cooksonii (Balme) Dettmann, 1963, -23093; 39; 5008b; 105/15.
Figure 8  Chomotrilletes sp. -23044; 19; 4986b; 89/3.
Figure 9  Rouseisporites simplex (Cookson and Dettmann) Dettmann, 1963, -23016; 19; 4986b; 120/3.4.
Figure 10 Rouseisporites reticulatus Pocock, 1962, -23045; 19; 4985b; 115/10.4.
Figure 11 Kraeusslisporites majus (Cookson and Dettmann) Dettmann, 1963, -22994; 17; 4983b; 100.4/11.2.
Figure 12 Aequitriradites verrucosus (Cookson and Dettmann) Cookson and Dettmann, 1961, -22992; 13; 4978a; 99/3.5.
Figure 13 Aequitriradites spinulosus (Cookson and Dettmann) Cookson and Dettmann, 1961, -23010; 19; 4985b; 96/20.6.
Figure 14 Cyatheacidites tectifera Archangelsky and Gamerro, 1956, -23081; 28; 4995b; 96.3/22.
Figure 15 Densoisporites perinatus Couper, 1958, -23123; 17; 4983b; 101/18.
Figure 16 Polypondisporites sp. 2, -23018; 20; 4987b; 106.5/21.
Figure 17 Polypondisporites sp. 3, -23019; 20; 4987b; 93/21.
Figure 18 Punctatosporites sp., -23063; 24; 4991b; 76/15.8.
Figure 19 Laevigatosporites haardtii (Potonié and Venitz) Thomson and Pflug, 1953, -23057; 23; 4990b; 98/19.8.
Figure 20 Laevigatosporites gracilis Wilson and Webster, 1946, -23056; 23; 4990b; 85/11.4.
Figure 21 Classopollis I, -22980; 48; 5024b; 82/20.7.
Figure 22 Classopollis IV, -22975; 47; 5023b; 103.7/7.8.
Figure 23 Classopollis V, -22978; 22; 4989b; 121.6/21.4.
Figure 24 Classopollis VI, -22979; 20; 4987b; 87.5/21.3.
Figure 25 Classopollis III, -23126; 27; 4993b; 100.5/18.8.
Figure 26 Araucariacites australis Cookson, 1947, -23100; 40; 5010b.1; 78/3.
Figure 27 Inaperturopollenites I+II, -23105; 43; 5016b; 122.5/8.6.
Figure 28 Inaperturopollenites limbatus Balme, 1957, -23120; 47; 5023b.1; 90.7/15.4.
Figure 29 Inaperturopollenites VI, -22971; 47; 5023b; 93/21.6.
Figure 30 Inaperturopollenites VII, -23125; 27; 4993b.1; 80/21.4.
Figure 31 Inaperturopollenites VIII, -23130; 20; 4987b; 92.4/21.4.
Figure 32 Tsugaepollenites trilobatus (Balme) Dettmann, 1963, -23119; 48; 5024b.1; 124/6.8.
Figure 33 Tsugaepollenites dampieri (Balme) Dettmann, 1963, -23127; 18; 4984b; 80/10.3.
Figure 34 Vitreisporites pallidus (Reissinger) Nilsson, 1958, -23128; 18; 4984b; 88/21.
Figure 35 Vitreisporites sp. Singh, 1971, -23050; 22; 4989b; 111.4/22.5.
PLATE 4

Figures 1-18 are magnified ×500; Figures 19-33 ×1000. Additional information in following order:
Negative Number; Core Number; Sample Number; Coordinates on Zeiss photomicroscope
mechanical stage.

Figure 1  Podocarpidites multesimus (Bolkhovitina) Pocock, 1962, -23116; 46; 5022b; 115/4.
Figure 2  Podocarpidites marwickii Couper, 1953, -22981; 19; 4985b; 107.3/15.
Figure 3  Podocarpidites ellipticus Cookson, 1947, -23129; 19; 4985b; 76/22.
Figure 4  Microcachrydites antarcticus Cookson, 1947, -23078; 19; 4985b; 90.5/21.
Figure 5  Phyllocladidites sp., -23011; 17; 4983b; 122.3/8.
Figure 6  Alisporites bilateralis Rouse, 1959, -23115; 45; 5021b; 114/16.7.
Figure 7  Alisporites similis (Balme) Dettmann, 1963, -23118; 40; 5010b; 109/20.3.
Figure 8  Podosporites sp., -23042; 17; 4983b; 111.5/21.
Figure 9  Perinopollenites halonatus Phillips and Felix, 1971, -23053; 23; 4990b; 95.2/22.
Figure 10 Schizosporis cooksonii Pocock, 1962, -23064; 24; 4991b; 115/14.3.
Figure 11 Monosulcites perspinosus Couper, 1953, -23009; 19; 4985b; 89/11.6.
Figure 12 Cycadopites nitidus (Balme) de Jersey, 1964, -23098; 41; 5013b; 89.3/19.5.
Figure 13 Equisetosporites multistriatus Pocock, 1964, -23000; 19; 4986b; 96.5/10.5.
Figure 14 Equisetosporites fissuratus Phillips and Felix, 1971, -23065; 24; 4991b; 105/19.7.
Figure 15 Equisetosporites virginiaensis (Brenner) Singh, 1971, -23087; 35; 5002b; 116/2.3
Figure 16 Equisetosporites rousei Pocock, 1964, -22996; 18; 4984b; 107/11.
Figure 17 Equisetosporites barghoornii Pocock, 1964, -22987; 39; 5008b; 1; 85.3/16.
Figure 18 Equisetosporites concinnus Singh, 1964, -23077; 19; 4985a; 112/12.
Figure 19 Steevesipollenites sp., -23151; 22; 4989b; 87.6/22.
Figure 20 Liliacidites intermedius Couper, 1953, -23131; 24; 4991b; 101/14.9.
Figure 21 Liliacidites crassatus Singh, 1971, -23143; 23; 49906; 120/22.2.
Figure 22 Liliacidites peroreticulatus (Brenner) Singh, 1971, -23139; 24; 4991b; 120.7/15.8.
Figure 23 Liliacidites trichotomosulcatus Singh, 1971, -23135; 24; 4991b; 80.3/21.2.
Figure 24 Liliacidites dividuus (Pierce) Brenner, 1963, -23133; 24; 4991b; 111/20.
Figure 25 Liliacidites inaequalis Singh, 1971, -23148; 23; 4990b; 124/13.6.
Figure 26 Clavatipollenites couperi Pocock, 1962, -23134; 24; 4991b; 107/23.
Figure 27 Clavatipollenites hughesi Couper, 1958, -23132; 24; 4991b; 92/20.3.
Figure 28 Clavatipollenites minutus Brenner, 1963, -23146; 23; 4990b; 91/21.
Figure 29 Tricolpites parvus Stanley, 1965, -23137; 24; 4991b; 122/20.
Figure 30 Tricolpites sp. 1 -23147; 23; 4990b; 82/15.
Figure 31 Tricolpites sp. 2 -23154; 24; 4991b; 81.3/14.5.
Figure 32 Tricolpites sp. 3 -23153; 22; 4989b; 106/20.9.
Figure 33 Tricolpites sp. 4 -23150; 22; 4989b; 115/23.
Figure 34 Porotrichotomosculcus sp. Phillips, 1971.
I. R. MCLACHLAN, E. PIETERSE

PLATE 5

All figures are magnified ×1000; excepting figures 21-23 ×500. Additional information in following order: Negative Number; Core Number; Sample Number; Coordinates on Zeiss photomicroscope mechanical stage.

Figure 1  Tricolpites sp. 7, -23160; 19; 4986a; 77/5.
Figure 2  Tricolpites sp. 9, -23168; 13; 4978b; 123/21.
Figure 3  Tricolpites sp. 10, -23166; 17; 4983b.1; 99/14.
Figure 4  Tricolpites sp. 6, -23156; 20; 4987b; 101.4/19.7.
Figure 5  Tricolpites sp. 5, -23151; 22; 4989b; 101.4/19.7.
Figure 6  Retitricolpites georgensis Brenner, 1963, -23155; 21; 4988b; 118/21.5.
Figure 7  Retitricolpites maximus Singh, 1971, -23169; 13; 4978b; 79/17.
Figure 8  Retitricolpites ellipticus Van Hoeken Klinkenberg, 1966, -23142; 24; 4991b; 98.5/13.7.
Figure 9  Psilatricolpites parvulus (Groat and Penny) Norris, 1967, -23141; 24; 4991b; 115.6/14.4.
Figure 10 Striopollenites sp., -23159; 19; 4985b; 111/16.
Figure 11 Scollardia steevesi Srivastava, 1966, -23163; 18; 4984b; 76/20.5.
Figure 12 Tetracolpate, -23162; 19; 4985b; 106/7.
Figure 13 Fraxinoipollenites venustus Singh, 1971, -23144; 23; 4990b; 120/22.2.
Figure 14 Fraxinoipollenites rotundus Phillips and Felix, 1971, -23140; 24; 4991b; 80/20.
Figure 15 Polycolpate -23158; 19; 4985b; 86/16.7.
Figure 16 Gemmatricolpites scabrat us Van Hoeken-Klinkenberg, 1964, -23149; 23; 4990b; 123/14.3.
Figure 17 Triporopollenites pseudocanalis Phillips and Felix, 1971, -23136; 24; 4991b; 76/20.3.
Figure 18 Nyassapollenites albertensis Singh, 1971, -23161; 19; 4986b; 76/6.8.
Figure 19 Syncolpate, -23164; 17; 4983b; 110/17.6.
Figure 20 Tricolporopollenites kruschii (Potonié) Thomson and Pflug, 1953, -23138; 24; 4991b; 118.5/17.6.
Figure 21 Incertae sedis A, -23037; 17; 4983b; 118/6.5.
Figure 22 Incertae sedis A, -23035; 19; 4985b; 105/16.
Figure 23 Incertae sedis A, -23039; 18; 4984b; 104/15.7.
Figure 24 Cretaceisporites mulleri Herngreen, 1973, -49157; 19; 4985b; 78/22.
Figure 25 Triporate, -23170; 13; 4978b; 124/12.
Figure 26 Proteacidites sp., -23145; 23; 4990b; 119/21.
Figure 27 Proteacidites annularis Cookson, 1950, -23165; 17; 4983b; 101.4/16.7.
Figure 28 Cupaneidites sp., -23167; 13; 4978a.1; 110/15.4