PERMIAN PALYNO MORPHS FROM THE NUMBER 5 SEAM, ECCA GROUP, WITBANK/HIGHVELD COALFIELDS, SOUTH AFRICA.

by

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ABSTRACT

A palynological study of the number 5 seam in the Ecca group has yielded a wide variety of miospores, with a lateral and vertical consistency in their relative abundance, diversity and composition. Striate bisaccate pollen genera predominate, particularly Protohaploxypinus Samoilovich emend. Morbey 1975, Striatopodocarpites Zoricheva & Sedova ex Sedova emend. Hart 1964 and Weylandites Bharadwaj & Srivastava 1969. On a regional scale the number 5 seam palynomorphs correlate both quantitatively and qualitatively with Biozone F of MacRae (1988) from the Waterberg and Pafuri coal-bearing basins, and Hammanskraal plant locality. Broad palaeoenvironmental inferences drawn from both the palynology and sedimentology of this seam, support a flood plain setting, comprising shallow wide open pans and peat swamps interspersed with wide water-logged mud flats. The surrounding highlands would have been forested mostly by plants adapted to wind dispersal with colonisation of the levees and margins of small ponds by spore producers. The age of the number 5 seam is tentatively suggested as Guadalupian, which in turn is equated with the Tatarian (European Standard usage); Midian to Dzhulfian (Tethys usage).

KEY WORDS: Ecca, Karoo, Palynology, Permian, Biostratigraphy.

INTRODUCTION

The coalfields falling within the study area are part of the northern Karoo Basin and are situated approximately 100km to the east of Johannesburg (Figure 1). In this area a major depositional sequence of 120m is represented. This sedimentary package contains six bituminous coal seams and the sequence is underlain by diamictite of the Dwyka Group or pre-Karoo basement rocks. Coal seams are numbered 1-6 from the base. The No 6 seam is laterally impersistent and is rarely found in the Witbank and Highveld Coalfields.

PREVIOUS PALYNOLOGICAL INVESTIGATIONS

To date the only published palynological work on the number 5 seam in the Witbank and Highveld Coalfields has been that of Falcon et al. (1984), who documented the qualitative/quantitative characteristics of samples from five main seams (1-5) at Greenside Colliery. Palynological comparisons of these seams were made using a palynobiostatigraphic type sequence from Zimbabwe (Falcon 1975, 1978).

MATERIALS AND METHODS

The number 5 seam in the Witbank/Highveld Coalfields varies in thickness laterally, but generally averages about 2.5 metres. For the present study four mine sites were investigated, namely Matla, Khutala, Greenside and Rietspruit.

Twenty to thirty samples, each weighing ± 500 grams, were collected from a number of sites at each mine. Extraction of the palynomorphs from the samples was carried out using a routine process developed at the U.S Geological Survey (Dohler 1980). This process enabled the rapid maceration of a wide variety of lithotypes, and individual steps were carried out according to the characteristics of each of the samples.

Visual counts of a minimum of 250 and maximum of 500 miospore specimens were undertaken. The relative abundance of species involved absolute counts within the first 250-500 and the supra-generic analysis comprised of these initial 250-500 miospores.

GEOLOGY

The Karoo Basin of South Africa contains the subcontinent’s most complete geological record of late Palaeozoic to early Mesozoic ‘Gondwanan’ sediments (Le Blanc Smith 1980). This asymmetrically filled basin represents a depository formed between the Cape Fold Belt to the south and the Kaapvaal Craton to the north.

In 1980 the South African Committee for Stratigraphy introduced a formal lithostratigraphic nomenclature for the Northern Karoo Sequence, which replaced the Lower, Middle and Upper subdivisions of the Ecca Group with the Pietermaritzburg Shale Formation, the Vryheid Formation, and the Volksrust Shale Formation, respectively (Figure 2).
Coal seams in the Witbank and Highveld Coalfields are situated in the Vryheid Formation which conformably overlies the glaciogenic Dwyka Group or unconformably overlies pre-Karoo rocks. The rocks of the Karoo Sequence in the study area are represented only by the Dwyka Group and the Vryheid Formation. This is due to the northern pinch out of the Pietermaritzburg Shale Formation and the removal through erosion of the Volksrust Formation. The Dwyka Group comprises diamictites, mudrocks and sandstones, while the Vryheid Formation is dominated by grey mudrocks, sandstones and coal seams.

The regional stratigraphy in the northern Highveld Coalfield is essentially similar to that of the Vryheid Formation in the adjacent central Witbank Coalfield (Le Blanc Smith 1980). Cairncross and Cadle (1987) subdivided the Vryheid Formation into 6 informal Genetic Sequences which are each terminated by coal seams.

The 5 Seam Genetic Sequence comprises the interval of Karoo strata between the roof of the number 4 Upper Seam and the roof of the number 5 Seam. The number 5 Seam is laterally continuous over a large area and displays little variation in gross thickness and is characterised by negligible variations in lithostratigraphic composition (Cairncross & Cadle 1987).

The 5 Seam Genetic Sequence is represented by a thin, laterally continuous, brown glauconitic interlaminated sandstone-siltstone, capped by a sporadically developed number 4 Local Seam and a white well-sorted, glauconitic sandstone. The number 4 Seam is overlain by an upward-coarsening succession comprising, from the base upwards, carbonaceous siltstone, lenticular-laminated siltstone, interlaminated sandstone-siltstone, flaser-laminated sandstone and cross laminated sandstone, capped by the laterally continuous, uniformly thick number 5 Seam (Winter, Cairncross & Cadle 1987).
Figure 3. Species variation in the number 5 seam.
The Witbank Coalfield is separated from the Highveld Coalfield to the south by the Smithfield Ridge, a broadly east-west trending, crescent-shaped, topographically high ridge of felsites, granites and diabase of the Bushveld Igneous Complex (Le Blanc Smith 1980).

RESULTS

The qualitative and quantitative results of the study are presented graphically to show specific and supra-generic variation through the number 5 seam. Because of the consistency of the miospores both vertically and horizontally in the number 5 seam from each of the mines investigated, it was decided that composite species and supra-generic taxa graphs be constructed (Aitken 1993).

Accordingly the samples that yielded miospores from each mine site were placed into the category of Upper, Middle or Lower number 5 seam. The ranges for the given categories are:

Upper 5 seam = 0.00m..0.66m from the top of the seam
Middle 5 seam = 0.67m..1.33m from the top of the seam
Lower 5 seam = 1.34m..2.00m from the top of the seam

Figures 3 & 4 represent composite species counts for the number 5 seam samples from Matla, Khutala, Greenside and Rietspruit. Species range charts were not used in this study because of the limited stratigraphic profile investigated. For species range charts to be used one must be able to investigate a much larger stratigraphic profile where the initiation and termination of species may be expected.

A predominance of striate bisaccate pollen was found to occur, with the following distinctive species: *Striatopodocarpites cancellatus* (Balme & Hennelly) Hart 1965, *Striatopodocarpites fusus* (Balme & Hennelly) Potonie 1958, *Striatobieites multistriatus* (Balme & Hennelly) Potonie 1964, *Weylandites lucifer* (Bharadwaj & Saluja) Foster 1975 and *Protohaploxypinus* species. In addition, the presence of *Lueckisporites* (Potonie & Klaus) Jansonius 1962, *Corisaccites* and *Lunatisporites* Leschik emend. Madler 1964, although not recorded in large numbers, could indicate an initiation of these genera. In all, 26 striate species were identified and a large amount of morphological variation was seen to exist in the species examined suggesting that taxonomic revision might be necessary.

Within the number 5 seam the number of trilete species remained relatively high (18 in all), although they represent only a small proportion of the miospore fraction (8-11%). These species include: *Acanthotriletes tereateangulatus* Balme & Hennelly 1956, *Deltoidospora directa* (Balme & Hennelly) Norris 1965, *Apiculatisporis cornutus* (Balme &

The disacciatrilete and disaccitrilete forms include species belonging to Limitisporites Leschik emend. Klaus 1963, Alisporites Daugherty 1941 emend. Jansonius 1971 and Platysaccus Naumova 1939 ex Ishchenko 1952. Monolete and plicate forms represent a small fraction of the assemblage with Gnetaceepollenites sinuosus (Balme & Hennelly) Bharadwaj 1962, Marsupipollenites triradiatus Balme & Hennelly 1956 and M. striatus (Balme & Hennelly) Foster 1975 comprising the major portion of the plicate fraction. Gnetaceepollenites sinuosus is found in relatively large numbers in the number 5 seam. This species is used in Australian biostratigraphic schemes (Kemp et al., 1977) to identify Upper Stage 4a. Figure 5 illustrates the variation in supra-generic taxa in the seam.

The following major trends in miospore content were observed:

i) An abundant striate bisaccate pollen (26-61%);
ii) A large proportion of triletes are represented above the number 5 seam (51%). However, within the number 5 seam they represent only (8-12%) of the miospore fraction;
iii) The remaining supra-generic taxa constitute a small fraction of the assemblage, disacciatriletes (4-7%), disaccitriletes (0-5%), zonates (3-13%), monosaccates (2-6%), plicates (2-8%), monoletes (1-4%), aletes (1-2%) and jugates (0-1%).

**DISCUSSION**

Within the number 5 seam the spore/pollen ratio is 3:1. Above the number 5 seam, this trend is reversed with the spores predominating, particularly the triletes and zonates. Of particular interest is the consistency of supra-generic taxa readings horizontally in the seam. A major change in the taxonomy of miospores is evident.

![Figure 5. Quantitative variation of supra-generic taxa in the number 5 seam.](image-url)
<table>
<thead>
<tr>
<th>SPECIES NAME</th>
<th>LOCALITY</th>
<th>SAMPLE</th>
<th>SLIDE</th>
<th>NEGATIVE</th>
<th>X-Y</th>
<th>SIZE μm</th>
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</thead>
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Figure 6. Selected tribete, monolette and aleate palynomorphs from number 5 seam.
above the number 5 seam. This can be attributed to a change in the palaeodepositional environment. The vertical consistency of supra-generic taxa in the number 5 seam shows that no major floral changes occurred in the accumulation of this peat swamp and the plant forms were well established in this environment. The horizontal consistency of supra-generic taxa at all of the mine sites also reflects a stable flora and confirms that the same seam was sampled.

The spore colour index technique has been used in the past to determine the degree of thermal maturation of carbonaceous sediments by differences observed in the colour of organic matter (Batten 1981; Burme & Kantsler 1977; Correia 1971; Dow 1977 & Stalpin 1969, 1977). The technique involves an expression of the colour range of organic matter from transparent light yellow, with a value of 1 to opaque black with a value of 5. This particular method has also been more commonly termed thermal alteration index (T.A.I.).

The palynological material from the number 5 seam samples is a dark orange to brown colour. The organic material would therefore be assigned a T.A.I. of between 3.0 and 3.5 with the equivalent vitrinite reflectance (% RoV) of 0.7 to 1.25.

This compares favourably with a figure of 0.7% RoV quoted for the number 5 seam at Greenside mine (Boshoff et al., 1993).

**REGIONAL CORRELATION**

*(SOUTH AFRICA)*

The number 5 seam samples from the Witbank and Highveld Coalfields show a distinctive miospore assemblage with the striates clearly dominant. The supra-generic taxa trends illustrate a high degree of horizontal and vertical uniformity, further supported by a consistent species pattern evident from all the mine sites.

Previous studies of this coal seam from Greenside mine by Falcon et al. (1984) indicated an assemblage consisting of *Striatopodocarpites, Protohaploxyphinus, Weylandites* (as Vittatina), *Alisporites* (as Sulcatisporites), *Lueckisporites* (rare), *Gnetaceae pollenites* and *Cirratiradiates* species.

Equally high numbers of *Alisporites* (Sulcatisporites) and *Protohaploxyphinus* species give an approximately equal proportion of striate and non-striate bisaccates were recorded (Falcon et al. 1984, Figure 3). However, the present study revealed a higher proportion of striate bisaccates (Figures 3 & 5). Falcon et al. (1984 Figure 3) show the number 5 seam correlated with biozone IV G; their figure 4a shows biozone IV G to have striate bisaccates as the most abundant supra-generic taxon.

A possible difference in the striate/non-striate bisaccate proportions between these two studies may be due to regional vegetational differences in the number 5 seam. This study does, nevertheless, show a consistent trend, with the striate bisaccate forms being far more abundant than the non-striate forms in the ratio of 3:1.

There is, however, a large similarity between the two studies in the species identified, with the presence of *Weylandites lucifer* (Vittatina africana), *Striatopodocarpites cancellatus*, *Striatopodocarpites fusus*, *Striatopodocarpites rarus* (Figure 7, no.21), *Lueckisporites virkkiae*, *Lueckisporites species*, *Gnetaceae pollenites sinuosus* (Figure 7, no.13), *Protohaploxyphinus species* (Figure 7, no's 14,23; pl.3, no's 27,30), *Marsupipollenites striatus*, and *Marsupipollenites triradiatus* (Figure 6, no.9). *Granulatisporites trisimus* (Figure 6, no.7) was also present in significant proportions (24% in sample 76). Falcon et al. (1984) also observed that the number 5 seam had a higher and more varied amount of striate bisaccate forms than the number 4 seam.

Falcon et al. (1984) proposed four Zones and five Sub-Zones for the Witbank Basin. These Zones ranged from Zone I at the base of the coal sequence to IV at the top of the number 5 seam. The number 5 seam was placed in Zone IV, Sub-Zone G with an equal proportion of striate and non-striate bisaccates being a major characteristic.

Sub-Zone G on the other hand was shown to have a larger proportion of striates to the non-striate bisaccates (Falcon et al. 1984). If this is indeed the case, then IV, Sub-Zone G is more in line with the findings of the present study. If Sub-Zone G has an equal proportion of striate and non-striate disaccates (Falcon et al. 1984) and Zone IV H a higher proportion of striates than non-striate disaccates then the number 5 seam is correlated with Zone IV H. This would also be supported by a higher proportion of the genus *Weylandites* (as Vittatina, Falcon et al. 1984).

MacRae's Biozone F is of particular interest as it shows a great deal of similarity to the number 5 seam miospore assemblage. Species in common with the Biozone F assemblage include: *Striatopodocarpites cancellatus; Striatopodocarpites rarus* (Figure 7, no 21); *Deltoidospora directa* (Figure 6, no 3); *Concavisporites mortonii* (de Jersey) de Jersey 1962; *Granulatisporites microgranifer* Ibrahim 1933; *Granulatisporites papillosus* Hart 1965; *Apiculatisporis levis*; *Laevigatosporites vulgaris* (Ibrahim 1933); *Horriditriletes ramosus* (Balme & Hennelly) Bharadwaj & Saluja 1964; *Lophotriletes novicus* Singh 1964; *Acanthotriletes tertevaebulatus* (Figure 6, no 26); *Cycadopites foliicularies* Wilson & Webster 1946; *Alisporites potoniei* (Lakanhal, Sah & Dube) Somers 1968 (Figure 7, no 24); *Platysaccus papilionis* Potonie & Klaus 1954; *Platysaccus radialis* (Leschik) Clarke 1965; *Protohaploxyphinus goraensis* (Potonie & Lele) Hart 1964 (Figure 9, no 30); *Protohaploxyphinus limpidus* (Balme & Hennelly) Balme & Playford 1967; *Protohaploxyphinus haritii* Foster 1979 (Figure 7, no 23); *Protohaploxyphinus diagonalis* Balme 1970 and *Pterichipollenites gracilis* (Segroves) Foster 1979.

MacRae selected *Gnetaceae pollenites sinuosus* (Figure 7, no 13); *Striatopodocarpites fusus* and *Weylandites lucifer* as being distinctive species of
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<th>SLIDE</th>
<th>NEGATIVE</th>
<th>X-Y</th>
<th>SIZE µm</th>
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</table>

Figure 7. Selected plicate, zonate and bisaccate palynomorphs from the number 5 seam.
Biozone F. All of these are found to be present in significant numbers in the number 5 seam. *Thymospora pseudothiessenii* (Kosanke) Wilson & Venkatapal in 1963 which terminates just below Biozone F (MacRae 1988) is present in the number 5 seam and there are a number of species in the number 5 seam which are not listed as being present in Biozone F. These are *Corisaccites alutas* (rare), *Lueckisporites virkkiae* (Figure 9, no 28) (rare), *Lueckisporites* species (Figure 9, no 29) (rare), *Granulatisporites trisinus* (Figure 6, no 7) (abundant), *Lueckisporites* species (Figure 9, no 32) (very rare), *Limitisporites* species (Figure 7, no’s 15, 16) and *Columinisporites* sp. (Figure 6, no’s 10,11).

Comparison of the relative proportions of supra-generic taxa and the species profile would indicate a very close similarity between Biozone F and the number 5 seam. MacRae (1988) reports an increasing trend of striates and a decreasing trend of non striate forms towards the top of his Biozone F (striates 60-80%, disacciatriletes/disaccitriletes 10-20%).

It is suggested that the number 5 seam may be correlated with Biozone F (Figure 8). Alternatively, a new Biozone is indicated, based on the presence of *Corisaccites alutas*, *Lueckisporites virkkiae*, *Lueckisporites* species, *Granulatisporites trisinus* and *Lunatisporites* species.

The number 5 seam miospore assemblage is equated with the more broadly defined *Striatitri* florigzone from South Africa of Hart (1967). Species in common include: *Weylandites lucifer* (as *Vittatina africana*), *Striatitricarpodiscites cancellatus*, *Striatitricarpodiscites fusus* (as *S. paralicus*) and *Gnetaceapollenites sinuosus* (as *Schoppifossilinates sinuosus*).

A broad similarity exists between the miospore content of the number 5 seam and Zone 5 described from the northern Karoo Basin, South Africa (Anderson 1977). A high proportion of striates are present in Zone 5 and many species are common. These include *Protohaploxypinus goraensis* (as *Pityosporites goraensis*), *Striatitricarpodiscites cancellatus* (as *Protohaploxypinus cancellatus*), *Protohaploxypinus amplus* (as *Pityosporites amplus*), *Protohaploxypinus micros* (as *Pityosporites micros*) and various *Lueckisporites* species.

**PALAEOENVIRONMENTAL SETTING**


Climatic amelioration during the Late Carboniferous and Early Permian was accompanied by glacial thawing and retreat to the north and northeast of the present day Karoo Basin (Crowell & Frakes 1975; Stratten 1968). The retreat of these glaciers has been proposed as being pulsatory rather than continuous (Falcon 1986). In the early stages of the Vryheid Formation glaciogenic conditions still prevailed causing infilling of palaeo-valleys by glacioluvial braided alluvium (Cairncross 1989). Epicontinental coal-forming environments follow conformably above these paraglacial sediments and are related to major sedimentation across the entire northeastern stable shelf area of the Karoo basin.

This wedge of regressive, nonglacial, fluviodeltaic sedimentation is characterised by eight episodes of proggradation and transgression with many of the regressions closing with a peat bed (Falcon 1989). Coal seams in the Witbank and Highveld Coalfields are associated with fluviial and delta dominated flood plain environments. The number 5 coal seam represents a large accumulation of plant material and therefore suggests an area that was once extensively vegetated.

The number 5 seam is quantitatively characterised by the dominance of the pollen over the spore fraction, with the striate taxa representing ± 60% and disacciatriletes/disaccitriletes ± 15% of the miospore fraction. These two dominant supra-generic taxa represent grains that are adapted to wind dispersal (MacRae 1988). Combining this evidence with data from previous sedimentological studies a flood plain setting is proposed, comprising of shallow, wide open pans and peat swamps interspersed with wide, waterlogged mudflats.

The levees and margins of these mudflats were possibly colonised by the lower order spore producers. Cryptogam spore producers are also most likely to have occurred as part of the understorey on the lake/pond margins and as the primary colonisers of the emerged portions of the shallow depository.

The abundance of striates in the samples might indicate that well away from the margin of these mudflats a fairly stable forest vegetation of high order pollen producing plants was situated. Long distance wind blown transport of this higher order pollen could account for dominance of the striates in the number 5 seam.

The dramatic increase in the striates and the decrease in all other taxa could conceivably indicate a vegetational response to a change in climate. This possibly occurred because of the drifting of the sub-

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**Figure 8.** Correlation chart of Biozones in the present study with international chronostatigraphic units (adapted from MacRae, 1988)
<table>
<thead>
<tr>
<th>SPECIES NAME</th>
<th>LOCALITY</th>
<th>SAMPLE</th>
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<td>27. Protohaploxypinus amplus</td>
<td>Rietspruit</td>
<td>BPI/10/97.2</td>
<td>BPI/10/1387</td>
<td>X102.5/Y12.5</td>
<td>91</td>
<td></td>
</tr>
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<td>28. Lueckisporites virkiae</td>
<td>Rietspruit</td>
<td>BPI/10/97.3</td>
<td>BPI/10/1533</td>
<td>X103/Y8.5</td>
<td>73</td>
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<td>29. Lueckisporites sp.</td>
<td>Rietspruit</td>
<td>BPI/10/97.2</td>
<td>BPI/10/1358</td>
<td>X94.5/Y15</td>
<td>81</td>
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</tr>
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<td>30. Protohaploxypinus goraiensis</td>
<td>Rietspruit</td>
<td>BPI/10/97.2</td>
<td>BPI/10/1557</td>
<td>X114.5/Y2.5</td>
<td>87</td>
<td></td>
</tr>
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<td>31. Striatopodocarpites pantii</td>
<td>Rietspruit</td>
<td>BPI/10/97.2</td>
<td>BPI/10/1463</td>
<td>X112/Y17</td>
<td>103</td>
<td></td>
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<td>32. Lunatisporites sp.</td>
<td>Rietspruit</td>
<td>BPI/10/97.2</td>
<td>BPI/10/1432</td>
<td>X116/Y4</td>
<td>71</td>
<td></td>
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<td>33. Weylandites simplex</td>
<td>Rietspruit</td>
<td>BPI/10/97.1</td>
<td>BPI/10/1412</td>
<td>X117/Y12</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>34. Cannanoropollis densus</td>
<td>Rietspruit</td>
<td>BPI/10/97.1</td>
<td>BPI/10/1167</td>
<td>X125/Y7</td>
<td>115</td>
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<td>35. Cannanoropollis sp.</td>
<td>Khutala</td>
<td>BPI/10/97.2</td>
<td>BPI/10/1242</td>
<td>X124.5/Y5.5</td>
<td>85</td>
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<tr>
<td>36. Cannanoropollis densus</td>
<td>Malta/1</td>
<td>BPI/10/97.2</td>
<td>BPI/10/1168</td>
<td>X102.5/Y13.5</td>
<td>98</td>
<td></td>
</tr>
</tbody>
</table>

Figure 9. Selected striate bisaccate and monosaccate polynomorphs from the number 5 seam.
continent into lower latitudes, and signals the first stages of the warmer temperate climates of Beaufort Permo-Triassic times.

AGE
Palaeobotanical age determination for Permian sediments remains a controversial subject. Two approaches have been described. The first, direct correlation, is based on a bio- and chrono-stratigraphic correlation comparing fossil plant assemblages found in spatially separated areas and the second, indirect correlation where the age of the flora is determined by comparison with marine faunas (Kovacs Endrody, 1991).

These different approaches result in age determinations that frequently differ. Kovacs Endrody (1991) discusses the validity of these two approaches. It is considered beyond the scope of this paper to critically analyze these two approaches; ages referred to in the preceding section are subject to revision when more palynological information becomes available.

The number 5 seam was correlated with the upper portion of Biozone F of MacRae (1988). MacRae (1988) dated his Biozone F as extending from the Ummumian to the lower part of the Kazanian Age and Biozone F was tentatively suggested as having extended over the remainder of the Kazanian, including part of the Tatarian. The number 5 seam was also correlated with the *Striatti* Florizone for which Hart (1967) showed a Tatarian Age.

CONCLUDING REMARKS
An important palynological trend in Upper Permian sediments both in South Africa and its Gondwana counterparts is the emergence of abundant strigate bisaccate forms, in particular genera such as *Striatopodocearpites*, *Protohaploxypinus*, *Weylandites*, *Lueckisporites*, *Lunatisporites*, *Corisaclices* and *Guttulapollenites* Gouin 1965. In the stratigraphy, the number 5 seam is situated towards the top of the Vryheid Formation. This has led to this seam being placed in the Upper/Lower to Lower/Middle Permian Epoch and hence of Akastinian to Baigendzinian age. However, this study and previous work by Falcon (1984) and MacRae (pers. comm.) place this seam in the Lower Upper Permian Epoch, which in turn supports a Kazanian to Tatarian age. An investigation of material stratigraphically higher and lower in the South African succession than the number 5 seam is needed to help resolve the age discrepancies.

ACKNOWLEDGEMENTS
I would like to take this opportunity to thank, Drs A. Cadman and C.S. MacRae for their valuable assistance and support during the period of this study. Helpful comments and advice was also received from Drs R.M.S. Falcon, C.E. Gow, B.S. Rubidge, R. Rayner and Mr B. Milsteed. My sincere thanks go to Drs R.M.S. Falcon and G. Playford for reviewing this paper.

Funding for this project was made available by the University of the Witwatersrand and the Bernard Price Institute for Palaeontological Research.

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